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FLOOD FORECAST & WARNING SYSTEM EVALUATION, SUSQUEHANNA RIVER BASIN, NEW YORK, PENNSYLVANIA & MARYLAND: REPORT OF AN INTERAGENCY TASK FORCE

1979

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Flood Forecast & Warning System Evaluation Susquehanna River Basin New York, Pennsylvania & Maryland

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Flood Forecast & Warning System Evaluation

Susquehanna River Basin
New York, Pennsylvania & Maryland

Report of an Interagency Task Force prepared by the Susquehanna River Basin Commission for the United States Army Corps of Engineers, Baltimore District

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I. INTRODUCTION

Why This Analysis

Following the devastation resulting from Tropical Storm Agnes in June, 1972, the Corps of Engineers was directed by Congress to conduct a Flood Control Review Study of the Susquehanna basin. The purpose of the review study is to determine if any improvements or additions to the existing flood control system would be feasible as federal projects. Flood damage reduction alternatives in the basin are being reviewed. Flood forecasting and warning is the alternative that is being addressed in this report.

This report presents an evaluation of the existing flood forecasting and warning system for the Susquehanna River basin. The report provides a detailed description of the existing system, a review of its performance and makes an assessment of ways to "improve" the existing system.

Agency Participants

The Susquehanna River Basin Commission (SRBC) has previously completed a preliminary investigation of the basin flood warning system.* Because of that activity and the Commission's intergovernmental coordination responsibility, the Baltimore District Engineer, Corps of Engineers, requested the SRBC to chair an Interagency Task Force to undertake this analysis of the basinwide forecasting and warning system. Direct fundings for this study has been provided by the Susquehanna River Basin Commission, with supplemental funding provided by the Baltimore District Corps of Engineers. Interagency Task Force members are:

Lead Agency

Susquehanna River Basin Commission

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* Summary Public Information Meeting on Flood Forecasting & Warning System, Chemung River Basin, N.Y. March 1976.

Recommendations for an Improved & Expanded Flood Forecasting System for the Susquehanna River Basin, SRBC, September 12, 1973.

Federal

National Weather Service
U.S. Geological Survey
Corps of Engineers

State

New York State Dept. of Environmental Conservation
New York State Division of Military and Naval Affairs
Pennsylvania Dept. of Environmental Resources
Pennsylvania State Council of Civil Defense
Maryland Dept. of Natural Resources

Purpose of the River Flood Forecast and Warning System

The river flood forecasting and warning system in the Susquehanna River basin has been developed and is operated to provide advance warning of flooding conditions which threaten human life and can cause property damage. There are two types of warnings: (1) flash flood watch or warning, and (2) basinwide and river flood forecast warnings. Flash flood watches or warnings provide an advance alert of possible flooding situations in general areas. Basinwide river flood forecasts and warnings, on the other hand, predict water heights for specific points on the Susquehanna River and its major tributaries.

Overview of the System

The basinwide river flood forecast and warning system is operated by the National Weather Service (NWS), a component of NOAA (National Oceanic and Atmospheric Administration), Department of Commerce. Rainfall reports and river gage readings are assembled by the National Weather Service River District Offices (RDO's) at Buffalo, Albany and Harrisburg, and the Weather Service Office (WSO) at Williamsport, and sent to the Middle Atlantic River Forecast Center (MARFC) at Harrisburg. The Center prepares river flood forecasts and transmits them to the RDO's where the river forecast is issued to state and county agencies and the news media for public dissemination. Then it becomes the responsibility of the community and each individual to respond to the situation by taking whatever measures are considered necessary to protect life and reduce property damage.

Flash flood watches and warnings operate differently. A local office of the National Weather Service either based upon weather forecasts or upon receiving reports of changing weather conditions or heavy rainfall will issue, if warranted, a flash flood watch or warning directly to counties or areas of responsibility for which a flooding potential exists. This activity is not a function of the River Forecast Center.

Components of the System

The components of the flood forecasting and warning system, some of which are operated by different levels of government, are:

1. Data collection;
2. Data assembly;
3. Forecast preparation;
4. Forecast dissemination;
5. Reservoir regulation; and
6. Local action - response.

The data collection component consists of weather reports and predictions, rainfall reports, river level reports and reservoir data reports. Figure 1 shows data assembly points in the basin. Chapter III discusses this component.

Data assembly includes several different communications systems between data gathering points which forward collected data to the MARFC at Harrisburg. Telephone, teletype, computer terminals, and when needed, an emergency radio system operated by the Corps of Engineers are used. Figure 2 illustrates the data assembly and transfer system, and is described in Chapter IV.

All of the pertinent data obtainable is assembled at the MARFC for flood forecast preparation. Since many factors must be considered in preparing a forecast, a computer program is used to make the calculations. Flash flood watches and warnings which provide a quick alert of possible flooding are issued by any local National Weather Service when necessary. Forecast preparation is described in Chapter V.

The forecast dissemination system consists of telephone and teletype systems which transmit forecasts from

Figure 1. Step One: Assembly System for Precipitation and River Data Essential for Preparing Forecasts

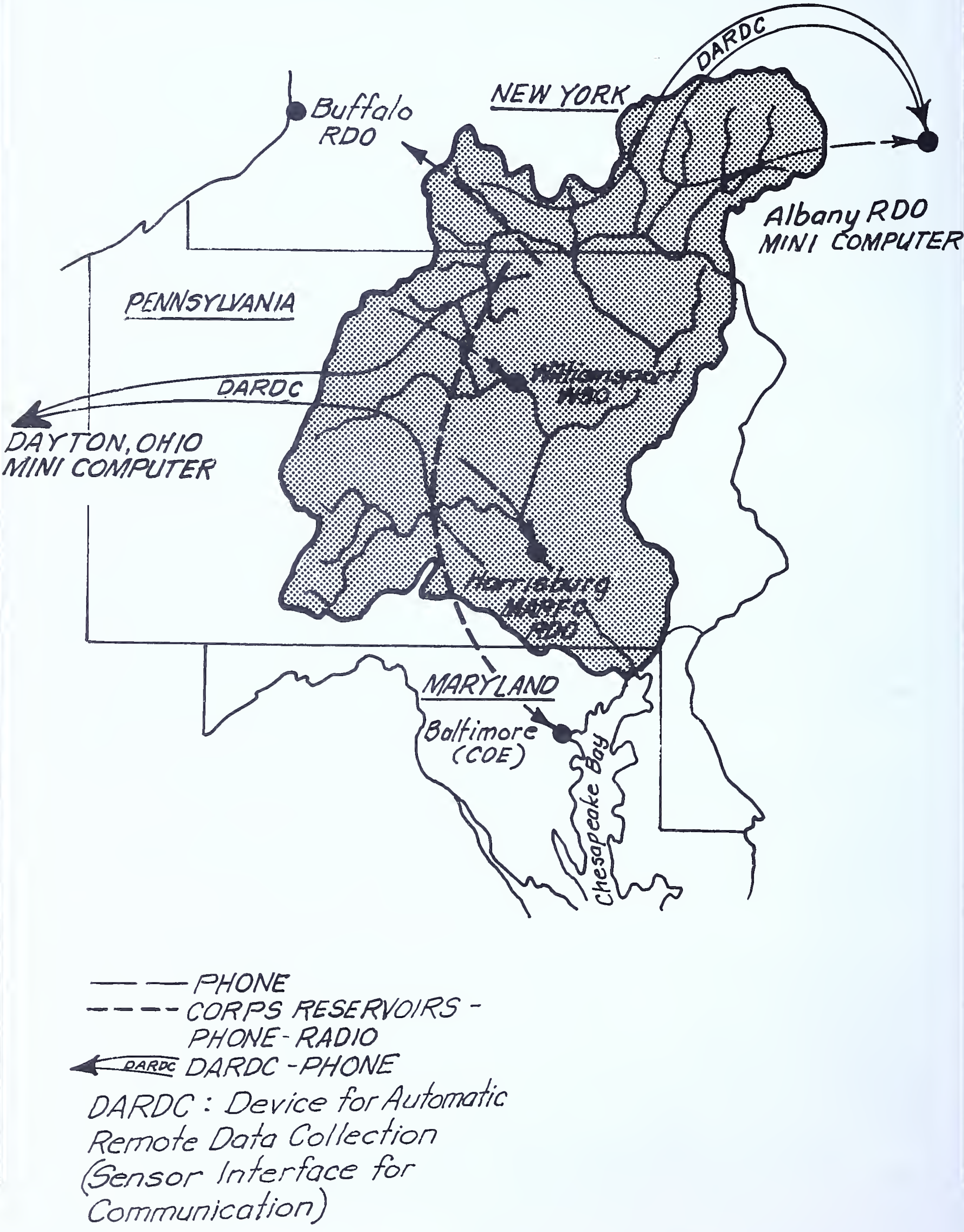
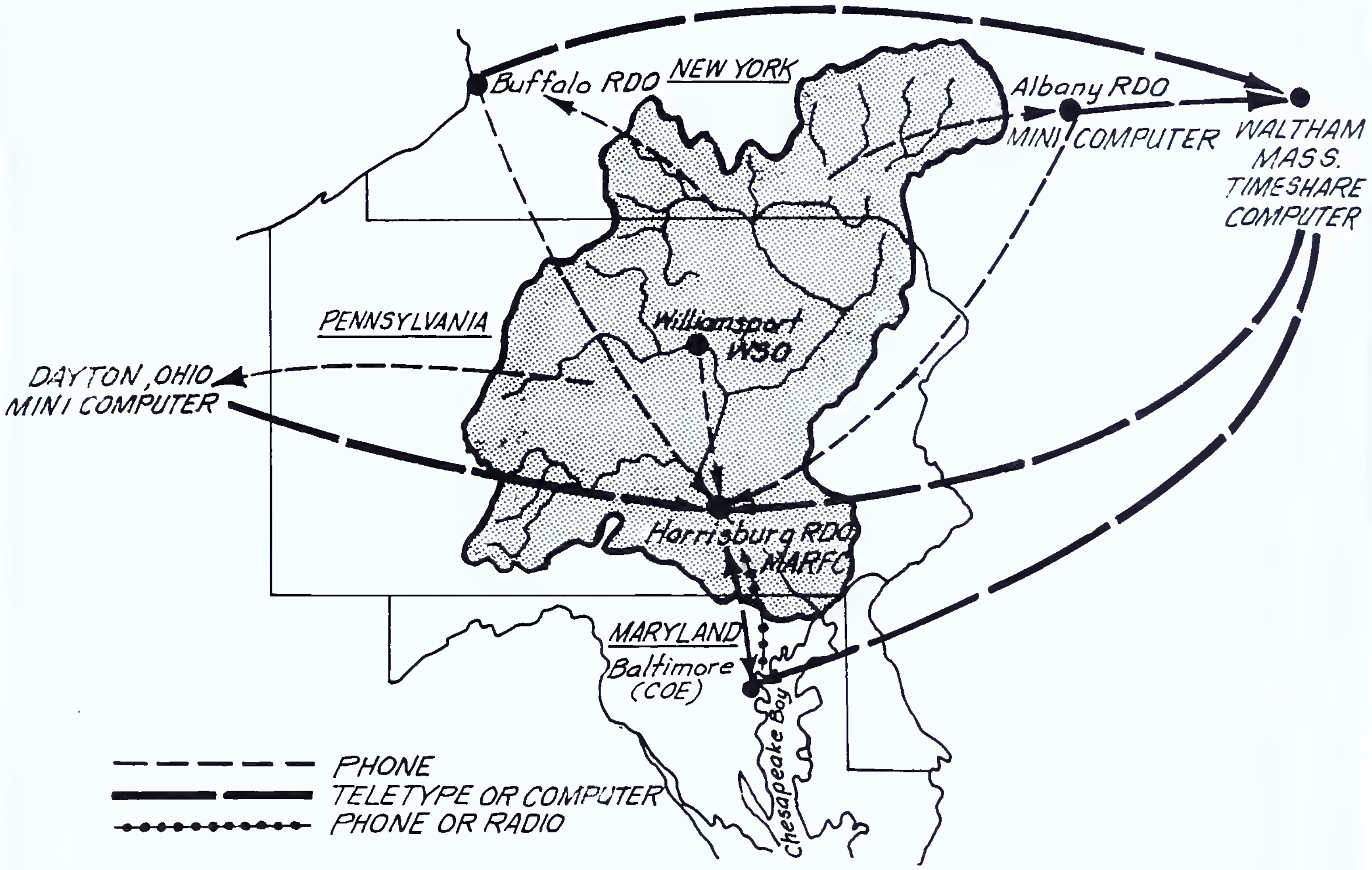


Figure 2. Step Two: Data Transfer System



the Harrisburg Center to RDO's at Albany and Buffalo. MARFC at Harrisburg also serves as a RDO. The RDO's then distribute the forecast to state and county agencies, mass media (radio, television and newspapers) who then issue public messages. Figure 3 diagrams the forecast dissemination system and is described in Chapter VI.

The Corps of Engineers operates a reservoir regulation system to reduce or modify flood flows. Reservoir regulation is managed from the District Reservoir Control Center (DRCC) at Baltimore, Maryland and is coordinated closely with the MARFC who include reservoir discharges in flood forecast procedures. Operational procedures and communications systems used for this purpose are discussed in Chapter VII.

Local action and response to flood warnings taken by county and local government agencies often determine the reactions of individuals to a flood warning. A general overview of the organization and operation of local action agencies is provided in Chapter VIII.

Each of the system's six separate components must be combined into a unified and coordinated working operation to make the flood warning system operate effectively. System operation relies upon all levels of government to perform their functions in a timely manner. Otherwise, forecasts will not be timely or reliable.

The coverage of this report is limited to areas of interagency concern such as equipment and information exchange issues. During the course of this system evaluation by the Interagency Task Force, other relevant issues of an interagency nature specific to the National Weather Service were discovered. While those issues are very pertinent to improving the basinwide flood forecast and warning system, they are not within the purview of the Interagency Task Force. Therefore, the Commission intends to present such matters in a separate, but related, report to the National Weather Service.

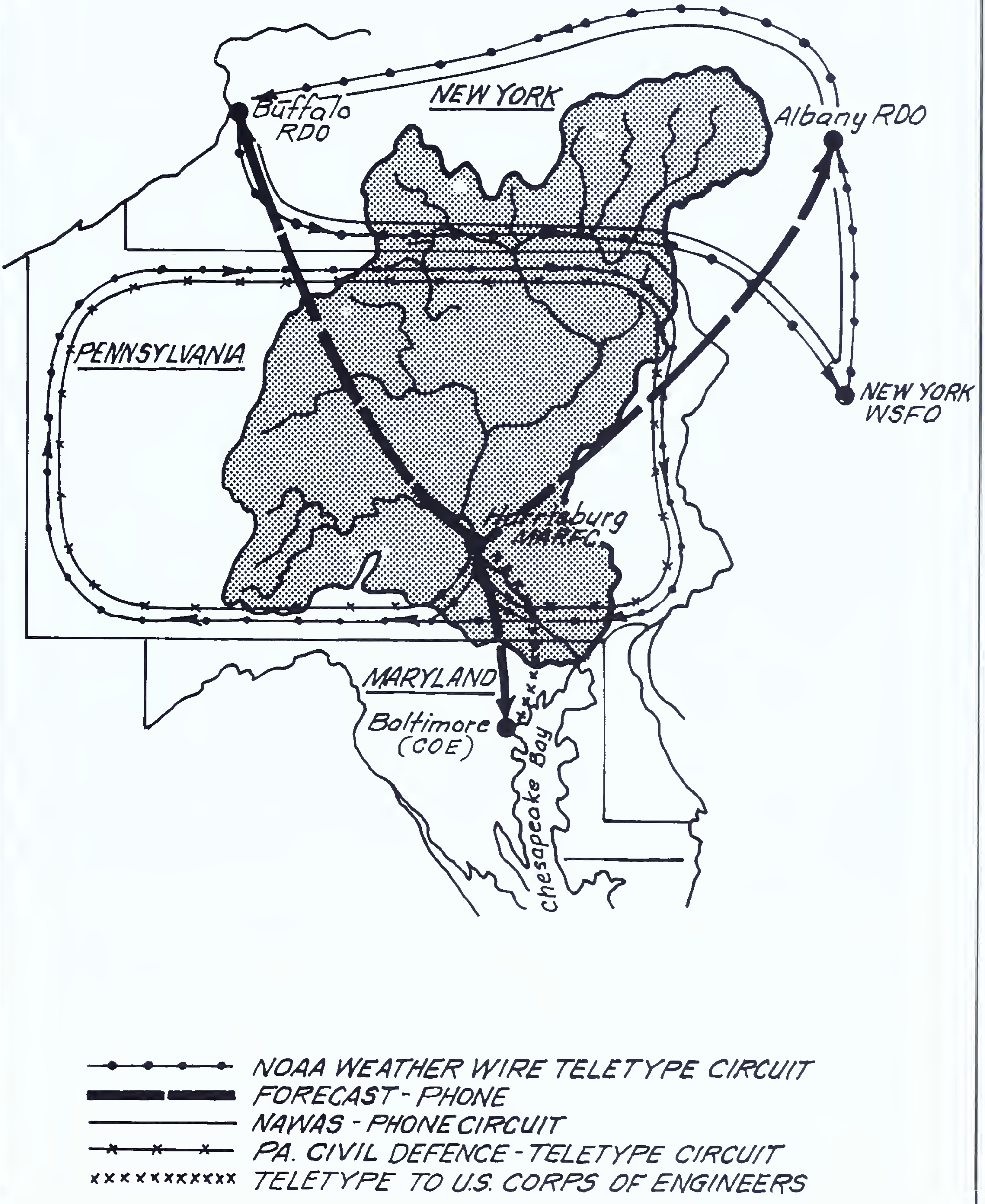


Figure 3. Step Three: Primary Flood Forecast Dissemination System

II. ORGANIZATION OF THE RIVER FORECAST SYSTEM

National Weather Service -- Middle Atlantic River Forecast Center

An Act of Congress* assigned the National Weather Service the responsibility for providing flood warnings. The Middle Atlantic River Forecast Center (MARFC) in Harrisburg, Pennsylvania, a field office of the National Weather Service, handles the drainage area of the Susquehanna River basin. Overall, the Center's area of river forecast responsibility encompasses the drainage into the Atlantic Ocean from the western edge of the Hudson River basin south to the Virginia-North Carolina border (Figure 4).

The Center's responsibility is to obtain necessary data and prepare computer forecasts routinely for about 150 points of which 38 are in the Susquehanna River basin. Fourteen additional points are forecasted manually during flooding situations and all 52 points are issued to the public. In the case of a major storm, such as with Agnes (1972), on the East Coast, however, flood forecasts are also needed and being prepared simultaneously for 98 additional points in other river basins.

With present resources (staffing for one full shift per day for five days) it is impossible for MARFC to provide timely forecasts on a 24-hour basis for all streams in the basin. Some streams crest so quickly after (or during) rainfall that there is not enough time for the Center to collect data, prepare a forecast, and then disseminate the forecast with adequate warning time. With regional storms, the need for forecasts and the demand for updated forecasts exceed the present capabilities of the system. In an attempt to meet some of these needs, local flash flood warning systems are developed in cooperation with the community.

River District Offices

To facilitate collection and transmittal of precipitation and river data, the MARFC's Susquehanna responsibility is organizationally subdivided among three River District Offices (RDO's) at Albany - North Branch of Susquehanna; Buffalo - the Chemung River basin; and Harrisburg - the remaining Susquehanna basin (although the

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* October 1, 1890 c. 1266 §3, 26 Stat. 653.

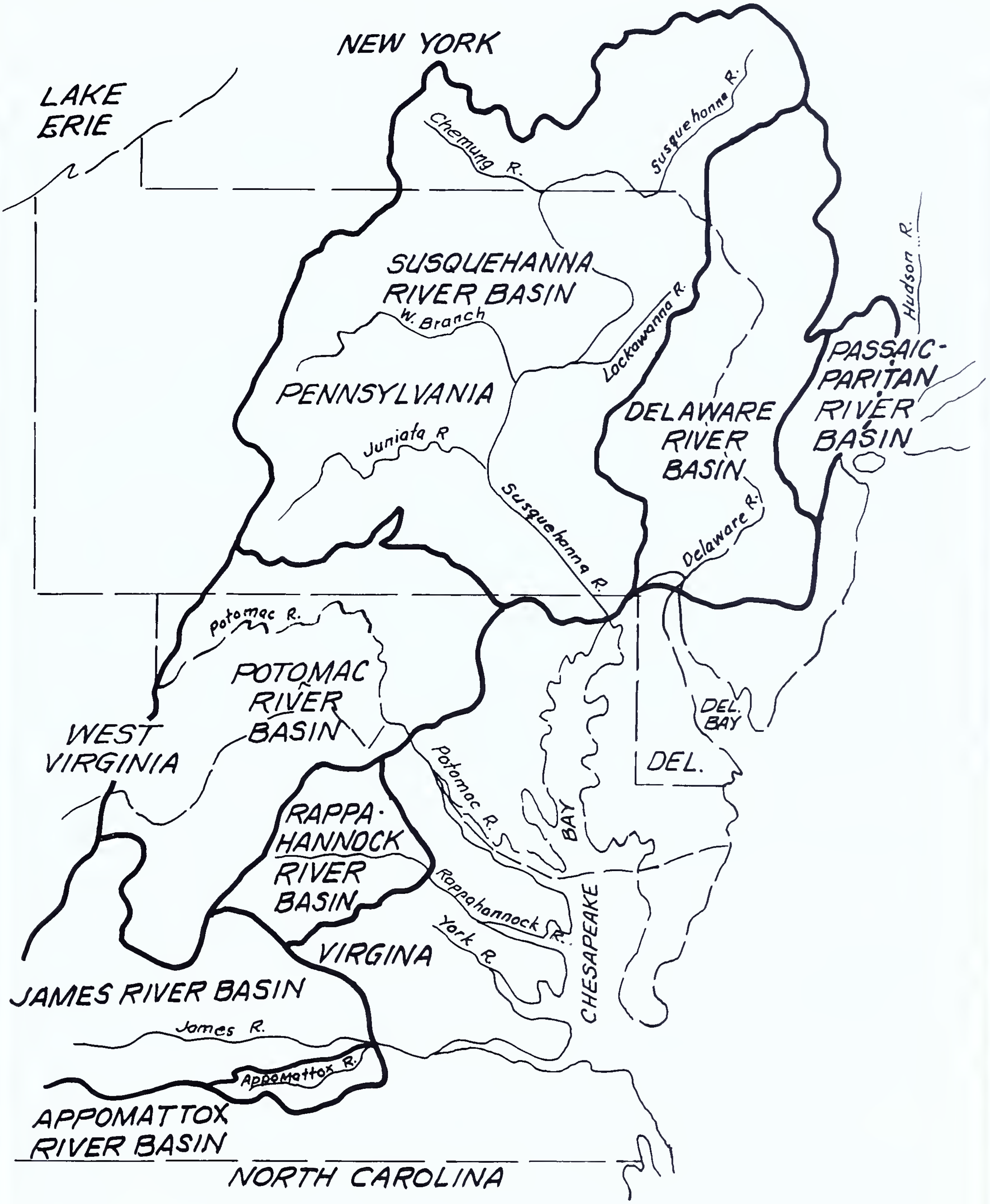


Figure 4. Area of Forecast Responsibility - Harrisburg Middle Atlantic River Forecast Center

Williamsport Weather Service Office serves as a sub-collection point for most of the West Branch). The Harrisburg RDO is co-located with the Middle Atlantic River Forecast Center in the Federal Office Building in downtown Harrisburg. Figure 5 shows data collection and flood forecast dissemination area responsibility for River District Offices in the Susquehanna River basin. Note that for New York State there are two RDO's, one covering each major subbasin, and both offices are located outside the basin.

The RDO's collect rainfall and river data, generally by telephone, directly from gages or observers located at predetermined points scattered throughout the basin. Data used to prepare and evaluate forecasts are sent to the Center from the RDO's via land lines communications (phone or teletype). The river forecasts prepared at the MARFC are then returned by the same communications systems to the RDO's for their guidance and public dissemination.

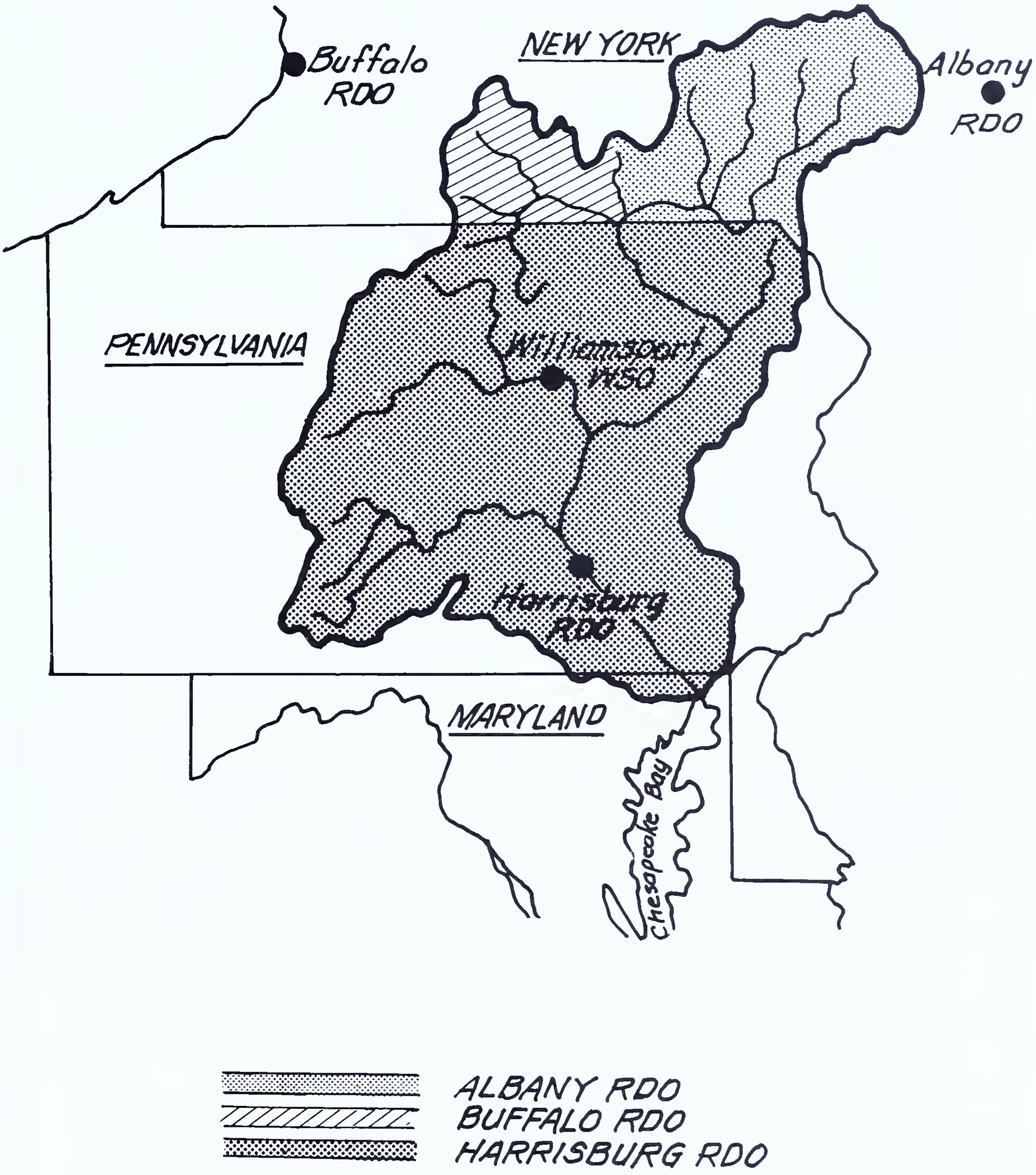
River forecasts are released by the RDO's on several communication networks to a variety of agencies at all government levels. These include state, regional and county civil defense, state and local police departments, Pennsylvania Dept. of Environmental Resources, New York Dept. of Environmental Conservation, some private industries, the various local news media, and the Corps of Engineers, Baltimore District.

Corps of Engineers, Baltimore District Flood Emergency Operation

The Baltimore District Office of the Corps of Engineers collects data to regulate its reservoirs. The Corps depends on MARFC river forecasts, but can do self-forecasting to assure efficient reservoir regulation in the event of loss of communications or delayed forecasts. In emergency situations, constant communications are maintained between the Corps and the MARFC.

The District Reservoir Control Center (DRCC) is responsibile for directing the gate operations at all of the Corps' dams in the river basin. The DRCC, manned by personnel of the Hydrology & Hydraulics & Water Quality Sections, issues instructions directly to dam operators. The DRCC assembles information provided by dam operators, MARFC and other NWS offices keeping currently informed of basin runoff potentials, antecedent rainfall, snow cover and water content, river stages, reservoir stages,

Figure 5. Data Collection and Flood Forecast Dissemination Areas for River District Offices in the Susquehanna River Basin



ice conditions, and forecasts of weather and river stages. The DRCC analyzes flood information received, maintains a running tabulation of the progress of the flood and accumulation of reservoir storage, and maintains a complete message log. Telephone, shortwave radio network and teletype are used by the DRCC for communications. The DRCC provides the River Forecast Center with its schedule of reservoir releases.

U.S. Geological Survey

The U.S. Geological Survey is responsible, with various federal, state and local cooperators, to install and maintain the river gaging system, including the operation of data collection platforms and telemetering instruments. This system serves a variety of purposes, river forecasting being just one; thus not all the available USGS gages are used by the MARFC.

III. DATA COLLECTION

Sensor Systems Used in Flood Forecasting

A complex system of sensors is used to collect rainfall and river level information for the flood forecasting system. Precipitation data is obtained from several different types of manually observed and automatic gages, and river levels are obtained from manually observed and automatic recording river gages. The different sensors or gages used in the data collection system are described in the following sections.

Cooperative observers, hired by the National Weather Service for a nominal fee, also relay river and/or rain data to local weather offices or the River Forecast Center. Observers and their reporting criteria are listed with the rain and river gages in Appendices A and B.

Precipitation Gages

High volume rainfall (and ensuing runoff) is a chief cause of flooding. Reliable knowledge of the rainfall over a specific watershed is essential to developing a river forecast and providing a warning. Thus, rainfall gages to collect and measure precipitation are basic elements in the system. There are 139 rain gages in the Susquehanna River basin, and an additional 24 adjacent to it are used by the MARFC.

The many different gage types,presently in use in the basin,reflect the gradual, piecemeal growth of the network. Different gages are required for different purposes. The Fischer-Porter gage is needed for telemetering while some of the other gages are easier for observers to use. The wedge gages are considerably less expensive than the others and help expand self-help programs at a minimal cost. Recording gages maintain continuous records for later analysis.

While some rain gages are owned by the Corps of Engineers and a few are owned by other agencies or individuals, most of the rain gages in the system are owned and serviced by the National Weather Service. The weighing and recording gages require periodic calibration by NWS field personnel.

Manually Observed Rain Gages

The Standard 8-Inch Gage operates by rain passing through a funnel-shaped collector into a cylindrical measuring tube placed inside an overflow can. The cross-sectional area of the measuring tube is equal to one-tenth the cross-sectional area of the collector. Rain is measured with a dipstick to hundredths of an inch. The gage is about 26 1/2 inches high and 8 1/4 inches in diameter and has a 2-inch rainfall capacity in the measuring tube. If rainfall exceeds the measuring tube's capacity, it is retained in the overflow can for additional measurement by emptying and refilling the measuring tube.

Two types of inexpensive plastic rain gages are in use. One is wedge-shaped for accurate measurements of light rainfall with a capacity of six inches. The other is a cylinder, four inches in diameter, with an 11-inch capacity. It has a small diameter inner tube for accurate measurements. The scales are embossed on the gages.

Automatic Recording Rain Gages

The Universal Weighing and Recording Gage operates by water passing from the collector into a bucket set on a platform of a spring or lever balance. This is linked to a pen which records collected precipitation on a chart (with .05-inch increments) mounted on a clock-driven drum. This gage has a 12-inch capacity and a record length of 1 day, 4 days or 7 days.

The Fischer and Porter Recording Gage records collected precipitation by punching a binary-decimal code on paper tape, in .10-inch increments, and can be programmed to punch as often as every five minutes. This gage's capacity is 19.50 inches and the record tapes collect information for one month before requiring a change.

The Tipping Bucket Gage operates by rain filling into a seesaw bucket device. Each bucket collects .01 inch of rain. This gage can record rainfall intensity as well as amount. During periods of heavy rainfall this gage may not provide accurate readings.

River Gages

An accurate river gaging system is required to develop day-to-day predictions. In flood situations, up-to-date information enables forecasters to improve predictions, especially for downstream areas. A river gage provides the river's water surface elevation (commonly known as stage) at a particular point in the natural drainage system within the basin. If the gage is "rated", meaning river flows are known for corresponding water surface elevations (flow vs. stage), then the volume of water passing the gage can be computed. Basic forecasting technique (described later) uses volume of flow, so gage ratings are needed to convert the observed stages to flow, and then the consequent forecasted flow back to stage.

In general, it is the responsibility of the U.S. Geological Survey (USGS) to build, operate and maintain gaging stations. Financing of the work is mostly done on a 50-50 cooperating basis with state and local agencies matching federal funds made available through the USGS.

The Dept. of Environmental Resources is the main State cooperator in Pennsylvania. The Dept. of Environmental Conservation is a major cooperator in the New York portion of the basin. The Dept. of Natural Resources is a major cooperator in the State of Maryland. The Corps of Engineers also provides considerable financial support.

Like the rain gage system, the river gage network developed gradually. The various gage types represent a variety of requirements and reflect budget and personnel limitations.

Manually Observed River Gages

Wire weight gages consist of a thin steel cable with a weight at the end wound around a metal drum and mounted on a bridge. A hand-crank is used to lower the weight to the water surface. A counter and graduated disk affixed to one end of the drum measure the length of cable let out between the check bar (stationary reference point just below the drum) and the water surface to measure the stage. Night time readings are difficult to obtain with this gage.

A staff gage is a graduated scale which is normally attached to a bridge. Most are mounted vertically (vertical staff gage) but some are mounted on an incline to follow the contour of the river bank (inclined or sloping staff gage). The length and range varies with each location. Some of the scales and numerals are made of iron with porcelain enamel finish and others are made of fiberglass. Night time readings are difficult to obtain.

A high-water staff gage is a vertical graduated scale which is attached to a bridge, building or other fixed object and is used to measure high river heights. Location is carefully chosen so that they are accessible for readings during high flows.

A crest stage gage is a vertical pipe inside of which is placed a graduated stick and a quantity of ground cork. The ground cork rises with rising water levels which enter the pipe through small openings near the bottom of the pipe. For later measurement, the bulk of the cork remains on the stick at the highest point that water reached. The crest stage gage is not normally used at the time that flood forecasts are being made, but is used later by the USGS to record the elevation of the highest flows or the crest of a flood.

Problems with manpower, finances and technology make it virtually impossible to have the entire gaging station and communication system absolutely dependable for an Agnes-magnitude flood. For this reason, the National Weather Service recommended that the U.S. Geological Survey erect and maintain external staff gages suitable for use by the general public at all of the more important gaging stations. At many stations equipment is sheltered inside structures and thus river stage readings are not available to the public. It was felt that external gages would provide readings by back-up observers using radio or other means at critical times if the established day-to-day communication system became inoperative.

Automatic Recording River Gages

Analog-To-Digital Recorder (ADR) is a recording device attached to river gages to record river levels. The ADR produces a punched tape record of water stage. Readings are made at intervals of 15 minutes to an hour depending on how the system is set and the record tape length varies.

A graphic recorder is a recording device attached to river gages to record river levels commonly referred to as river stage, water stage or stage. The graphic recorder traces continuous water stage readings on a strip-chart. Graphic recorders can operate for periods of 60 to 90 days.

Transmission Equipment for Automatic Gages

There are several different kinds of equipment that can communicate automatic precipitation and river gage readings to National Weather Service offices. Communications between the gages and the RDO's or the MARFC is the responsibility of the National Weather Service.

A telemark gage continuously measures river gage water stage and transmits a coded audio signal of stage over telephone lines when called by users. A series of "beeps" is counted by the caller to obtain the stage. The system includes a telephone, battery, battery case, buzzer assembly, service cable, float, float pulley, counterweight and beaded float cable. Up-to-date readings are always available provided the battery and other parts are operable. The telemark does not provide a record of stage,nor does it depend upon a recorder for its operation.

A Binary Decimal Transmitter (BDT) is a transmitting device coupled with the ADR river gage recorder. The BDT transmits an audio signal similar to the telemark when it is called.

The Device for Automatic Remote Data Collection (DARDC) is a compact electronic system used with the Fischer-Porter rain and ADR river gages to transmit data to the RDO's or MARFC. DARDC has its own power supply, a battery that lasts indefinitely with recharging by solar panels, and is acoustically coupled to a telephone line when normally used. However, DARDC can be wired into a two-way radio set if desired, and can also be used with satellite data collection systems. DARDC stored data can be updated at intervals of 15 minutes to one hour and is available upon remote command. When contacted by telephone the device transmits rapid data impulses. A terminal with an acoustic coupler is required to print the data, which are audible but unintelligible to the ear, or the data can be processed directly to computers. A lighted display is also available to attach to telephones for reading DARDC data impulses. MARFC has three independent systems to interrogate DARDC-equipped gages.

The recording river gages and telemarks are installed and maintained by the USGS. The electronic packages such as DARDC and BDT's are owned and maintained by NWS.

A complete listing of the 76 river gages used in the basin for river forecasting is presented in Appendix B.

Corps of Engineers -- Reservoir Regulation Data

To efficiently and safely regulate its reservoirs, the Corps of Engineers has a data collection system which complements the NWS system. Much of the data is rain and river information relayed by the National Weather Service. In addition, the dam tenders also report local data including precipitation, lake (reservoir) elevation, river stage at key locations downstream, snow depth and its water content (when pertinent), and dam gate setting. During normal periods, radio drills are held daily between the dams and the District Reservoir Control Center (DRCC) at 8:15 a.m.; but during flood periods radio contact is made as often as deemed necessary.

The DRCC receives river stage forecast data from MARFC at Harrisburg via radio, telephone and teletype. During normal periods the data is received daily for six stations in the basin. During flood periods the forecasts are received several times a day for all key stations in the basin. At times during flood events various data other than that described above are received by the DRCC via telephone and radio from Corps personnel in the field. These data include informal river elevation data, indications where flooding occurred, types of damages, etc. A detailed description of the Corps of Engineers' data gathering system is presented later in this report.

Weather Information

Accurate, up-to-date weather information is important for river forecasting. A wide range of meteorological information for weather forecasting such as temperature, wind, atmospheric pressure and radar data is used by a flood forecaster to monitor changing weather conditions. Weather systems affecting the basin have direct bearing on flood-related elements such as snowmelt, runoff potential and actual rainfall. The weather information received at the MARFC and its collection system are described briefly.

Hourly Weather Reports

National Weather Service Forecast Offices (WSFO), National Weather Service Offices (WSO), and Federal Aviation Administration Flight Service Stations (FSS) gather data specifically for weather forecasting and aviation services (Table 1). There are six stations in the basin that transmit hourly weather reports on wire services "A" and "C". (See Chapter IV.) These reports include sky cover, weather elements (rain, snow, fog, etc.), visibility, pressure, temperature, dewpoint and wind. Harrisburg, Binghamton and Avoca also report the percentage of possible sunshine to the MARFC on a daily basis.

Table 1

Sources of Weather Data
in the Susquehanna River Basin

Harrisburg, PA	(FSS)	Binghamton, NY	(WSO)
Altoona, PA	(FSS)	Avoca, PA	(WSO)
Philipsburg, PA	(FSS)	Williamsport, PA*	(WSO/FSS)

There are several stations outside the basin which may also be used to keep track of developing weather conditions (Table 2).

Table 2

Additional Sources of Weather Data
Outside the Susquehanna River Basin

Utica, NY	(FSS)	Philadelphia, PA	(WSFO)
Syracuse, NY	(WSO)	Allentown, PA	(WSO)
Bradford, PA	(FSS)	Martinsburg, W VA	(FSS)
Dubois, PA	(FSS)	Baltimore, MD	(WSO)
Pittsburgh, PA	(WSFO)	Washington, DC	(WSFO)

Radar Data

The National Weather Service Long Range Network Weather radars at Albany, New York City, Buffalo, Pittsburgh, Atlantic City and Patuxent River (Maryland) provide coverage in the Susquehanna basin. The radars have the capability to measure rainfall but automatic equipment is not presently installed. The radars show areas receiving precipitation in different sections of the basin, and the starting and ending time of rainfall. The hydrologic usefulness of these radars is limited however, because they are located too distant from most points in the basin.

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* Operates only 16 hours/day.

In 1977, local storm warning radars were installed at Binghamton, N.Y. and Harrisburg, Pa. which may prove to be more useful to river forecasters. The Harrisburg radar was operationally commissioned in June 1977 and the Binghamton radar in March 1978. The Binghamton station also serves as a Long Range Network Weather radar.

Snow Reports

There are several different sources of snow data. In season, the Corps of Engineers takes weekly snow surveys from the drainage areas above their reservoirs. Snow depth and water equivalent are reported for the snow survey sites. The total depth of snow on the ground and the amount of new snow are given in the regular morning reports by the Corps' District Reservoir Control Center.

The NWS cooperative observers include snow on the ground and new snow in their regular morning reports, but very few cooperative observers report the water equivalent of snow on the ground. Difficulty in measuring snow and snow cover has produced irregularity in observer reporting.

The National Weather Service and Federal Aviation Administration Flight Service stations carry snow reports on both wire services "A" and "C". Snow on the ground and new snow are reported each morning when there is more than a trace on the ground, and every six hours when more than a trace has fallen during the preceding six-hour period. Water equivalent is given whenever the average depth is two inches or more.

Temperature Reports

While all NWS cooperative observers report the temperature at the time of observation, many of the observers along with the National Weather Service and Federal Aviation Agency Flight Service stations report the daily maximum and minimum temperatures. Cooperative observers at stations listed in Table 3 report maximum and minimum temperatures.

Table 3

National Weather Service
Cooperative Observer Stations
Reporting Maximum/Minimum Temperatures

Towanda, PA
Carrolltown, PA
Loysville, PA
Lewistown, PA
Huntingdon, PA
Bainbridge, NY
Newport, PA
State College, PA
Montrose, PA
Germania, PA
Eagles Mere, PA
Chemung, NY
Emporium, PA
Millville, PA
English Center, PA
Wellsboro, PA
Selinsgrove, PA

Table 4 lists the federal agency offices (National Weather Service and Federal Aviation Administration Flight Service stations) reporting maximum and minimum temperatures.

Table 4

Federal Agency Offices
Reporting Maximum/Minimum Temperatures

Harrisburg, PA
Avoca, PA
Philipsburg, PA
Williamsport, PA
Binghamton, NY
Altoona, PA

Evaluation

There are 163 rainfall observation stations and 76 river gages used to gather basic data for the NWS flood forecasting system in the river basin. Additional rainfall data can be a valuable addition to the automatic data collection system. More information can be used if it is obtained on a regular basis.

Greater improvement can be accomplished by increasing the reliability of data sources. Without data available on a timely basis, there will be no forecast or a forecast of poor reliability with consequential low public credibility and response. Adequate maintenance has been and continues to be a major factor in system reliability. Developing a system of redundant data acquisition that is flexible, but comprehensive, using a variety of reliable data sources is more important than major increases in data points.

New radar installations are planned, and experimental work using satellite observations is underway. It is not known what value these new developments have for improving flood forecasting.

There have been and continue to be improvements in data collection equipment. Several DARDC rain and river gages have been installed. Satellite data collection platforms are installed or planned in the near future at over 40 river gages used for river forecasting. (See Appendix C.) This additional equipment will increase the amount of data reported automatically and provide an alternate method of data acquisition, thereby enhancing system reliability. DARDC provides a method for rapid data assembly by the ADAS computer system. (See page 25.)

A high quality maintenance program needs to be organized to insure that gaging equipment is constantly in operational condition. Missing data or inaccurate reporting have been a problem in the past. Coordination of maintenance schedules will be needed since there are several different supporting agencies. Long-term funding commitments and manpower allocations will be needed to operate the maintenance program.

Redundance is needed in the data collection communications system to provide back-up capability in case one method of data collection becomes inoperative. The system must be flexible enough to provide for rapid assimilation of alternate data sources. As increasing amounts of automatic recording equipment have been added to the system, observers have been eliminated with decreasing interest displayed by remaining observers in reporting observations.

DARDC river and rain gages can be queried over the telephone only by using special equipment. Local officials are thereby prevented from obtaining information directly, unless they obtain costly decoding devices. This hampers local operations but does avoid the problem of busy phone lines to gages during a flood.

Many river gages used in the system have back-up staff and river crest staff gages for use when automatic gage readings are unavailable, but there remains a large number which do not have the back-up gages. This is a serious deficiency since it prevents needed river gage readings from being obtained by both the NWS and local officials who provide accurate, updated forecasts. The most serious instances of this deficiency are in the limited number of back-up staff gages for the North Branch of the Susquehanna River above Waverly in New York State.

Data from telemark river gages is obtained by telephone calls. Often during emergencies, a large number of callers tie up the telephone preventing the NWS and other agencies with flood forecasting responsibilities from obtaining the data that they need. Therefore, some discipline and prioritization of usage scheme is needed to assure availability of data or access to it by the MARFC during an emergency.

The existing data collection system has developed over many years as a result of various sources financing the installation and maintenance of equipment. Review of Appendices A and B reveals that a multiplicity of state and federal agencies support the system. In reviewing the history of the development of the existing system, it is important to note that there have been many increases and decreases in this support, resulting in changes in the number of rain and river gages. A coherent, consistent and coordinated support program should be developed and maintained.

New local warning radar equipment has been installed at NWS offices in Binghamton and Harrisburg to improve the radar coverage in the Susquehanna River basin. These radar can be used to determine where rainfall occurs and provide an estimate of rainfall and amount. It will be some time before the effectiveness of this component's contribution can be evaluated. Automated rainfall estimating equipment is planned to be added at Harrisburg.

Satellite imagery of weather has potential for improving weather forecasting,but data handling and technical procedures are still being developed. Regular use of this equipment is still in the future. There are also possibilities for combined radar and satellite data usage. This is also in the experimental or development stage.

Finally, there is an increasing amount of local involvement in independent flood warning systems. Data assembly from self-help and neighborhood flash flood warning systems can provide a valuable initial alert to NWS offices that something is happening. This continuing interest by local civil defense and other agencies should be considered in the selection and replacement of regular NWS observers, thereby enhancing closer cooperation between the NWS and local organizations. Also, training and cooperative extension-type support by the NWS to local programs where interest is high will increase the performance of local self-help programs.

IV. TRANSMITTING DATA TO THE FORECAST CENTER

This section describes how the data, collected for forecasting as described in Chapter III, is transmitted to the forecast center. Since there are several different kinds of information and several different communications methods, this section will describe how the weather, rainfall and river gage data and reservoir regulation information is transmitted to the MARFC at Harrisburg where the forecast is made.

This section also includes a description of the data collection procedures used by NWS offices, and because there are so many ongoing improvements, a brief description is added of future methods of data acquisition and dissemination.

Weather Forecast Data Transmission

The following wire or telephone circuits are used for the transmission of weather forecast data to the forecast center.

Service "A" - This teletype information relates primarily to aircraft operation. It consists of hourly weather observations, radar data, severe weather reports, air terminal reports and aircraft observations. Six-hour precipitation totals are reported four times a day and at 7:00 a.m. a 24-hour total is reported. Maximum and minimum temperatures are given and snow reports are transmitted in season.

Service "C" - Most of the other reports of interest to a weather office come on this teletype circuit including synoptic weather reports from weather offices, state and area forecasts, air pollution reports, flood bulletins and many other special weather reports. The river district offices use the precipitation, temperature and snow reports from this curcuit.

Radar Report & Warning Coordination System - RAWARC is a national teletype network based in Kansas City. All types of weather information from offices around the country are fed into a computer and then disseminated back to the appropriate offices by predetermined programming. There is an alarm system which rings when a tornado warning, severe weather bulletin or similar urgent message is received. The river district offices in Buffalo and Albany occasionally use this circuit to transmit data to the MARFC.

A Facsimile Machine receives maps prepared in Washington and Kansas City to help local forecasters with their areas. Some of the many maps show the movement of weather systems, 5-day weather outlooks, upper air systems and radar summaries. Of special interest to the MARFC are the maps showing the expected amounts of rainfall during specified time periods.

Rainfall and River Data Transmission

Most data is transmitted over telephone and teletype equipment. Phones are in constant use calling observers, interrogating river and rain gages, and talking between National Weather Service offices. The teletype (TWX, Western Union) is used to exchange data with other agencies that have similar equipment. Some data are collected by automatic recording devices which are connected to river or rain gages. Computer terminals can automatically receive data from properly equipped river and rain gages on a predetermined schedule.

Data is obtained over the telephone from NWS BDT's and telemark river gages installed by the USGS and the Corps of Engineers. A river gage reading is obtained by dialing the desired gage and listening to (and counting) the number of "beeps".

Data from DARDC rain and river gages is obtained also by telephone interrogation. The signal obtained is sent through an acoustic coupler and the gage reading is then printed out by teletype.

Automatic Data Acquisition System - ADAS is used to save time and the manual dialing of a phone for DARDC data. Computers at Albany, New York; Dayton, Ohio; and Athens, Georgia are programmed to call a certain number of gages, store the data, compute any changes, call the teletype machine at the MARFC and print out a listing of relevant data. This service also provides a record copy during times when the office is closed. Almost all of the DARDC sites in the basin are covered by either the Albany or Dayton computers.

Computer terminals used with shared data systems provide quick access to much valuable hydrologic data. The computer terminals in various offices can relay or exchange information held in a shared data system. By entering the right code words, data (which are stored in the system) will be printed out at a terminal. Currently, MARFC receives data from the Albany and Buffalo RDO's via a time-share computer at Waltham, Massachusetts. The Corps of Engineers is also part of this system.

Reservoir Regulation Data Transmission

Corps of Engineers Radio Network - The Baltimore District, Corps of Engineers, has established a radio network between their District Office and all reservoir projects and dam maintenance sections. This enables them to instruct their dam tenders, spot trouble areas, and obtain data. The MARFC is included in this network and can send and receive messages by this system.

Normally, reservoir data is transmitted daily via time share computer, teletype (TWX), telephone or copied directly by the MARFC as often as it can listen directly to the radio drill. During flood periods almost constant contact is maintained between the Baltimore District Office and the MARFC. Data is transmitted several times daily via TWX, telephone and radio.

Gathered Data Collection Procedures

The NWS operates a phased data collection system. RDO's at Albany and Buffalo, New York; Harrisburg, Pennsylvania and the WSO at Williamsport, Pennsylvania gather data directly from observers and automatic recording equipment as described above. These collection points in turn relay the gathered data by computer terminal or telephone to the MARFC in Harrisburg. The Harrisburg RDO is co-located with the MARFC so no intermediate relay is needed. The Williamsport WSO collects and relays data from the West Branch of the Susquehanna River while Albany collects data from the North Branch and Buffalo for the Chemung River basin. See Figures 1 and 2 on pages 4 and 5.

In addition to the complex equipment just described, the observer plays an important part in providing additional data from many locations.

Observers are called (or call the RDO) on a regular basis, generally every morning around 7:00 a.m. to report temperature, precipitation, weather and river stage (where applicable). A number of rainfall observers are on "criteria". They call in only if a certain amount of precipitation has been exceeded (usually 1/2 inch) and then continue to report every six hours until the rain ends. All river observers report when the river reaches a certain stage and every six hours until it is below that stage. Observers are paid a few dollars a month depending on the number of observations made.

Future Methods of Data Acquisition and Dissemination

The inability to get a comprehensive picture of rainfall patterns and amounts during a severe storm greatly hampers effective forecasting. Power failures, evacuated observers and downed phone lines frequently prevent obtaining information from critical areas. Research programs are seeking ways to improve data reliability. This section describes new systems under study addressing problems experienced in the past with the existing system.

Satellite Data Collection

Space satellites have been built to gather and relay to the ground a multitude of data. Weather satellites have been in use for quite some time. Now the National Weather Service, U.S. Geological Survey, Corps of Engineers and the Susquehanna River Basin Commission are developing jointly a system wherein river and rainfall data will be continuously collected via geostationary satellite. When operational, the NWS, USGS and Corps will obtain data when needed by periodically interrogating the satellite by a computer on the ground. Various satellite systems and a map of probable data collection platform sites to gather and transmit data to the satellite are listed in Appendix C.

Automation of Field Operational Services (AFOS)

The National Weather Service is planning a new concept in station operation called AFOS. The forecaster on duty will sit before several TV-like monitors and select the data he needs to make a forecast. Weather and river district offices will be connected with each other and the National Weather Centers by the National Distribution Circuit. All types of information now handled by teletype and facsimile circuits will be entered into the system and stored in the computers. By pressing the right button, the desired information will be available. River stages and flood hydrographs can be stored and then projected when called, so the whole picture of a river basin can be reviewed quickly.

AFOS is expected to speed-up the movement of data and thereby result in more timely forecasts.

Evaluation

Obtaining accurate, up-to-date information during extensive storm periods is the major limitation to the present data assembly system. Unreliability and communications overloads during storms are problems with the present data system. The present NWS data assembly system relies primarily on land telephone circuits. The Corps of Engineers reservoir regulation communication system, which has a limited number of data points, is the sole exception.

Following Tropical Storm Agnes, the NWS reorganized the data assembly system. ADAS, the automatic data assembly system, is now used to gather data for MARFC at Dayton, Ohio and Albany, New York from a variety of communications channels. However, overloading of telephone lines currently slows down ADAS. High telephone rates for this system may restrain further improvement.

Installation of data collection platforms (DCP's) at over 40 river gages is nearly completed. MARFC is presently receiving this river gage data over a satellite data collection system. Completing the installations of DCP's at river gages and adding them to selected rain gages will provide a more rapid, reliable alternative communications route for MARFC.

The NWS river flood forecasting system needs the capability to verify data and forecasts through a feedback system to observers and gaging stations. There are separate reliable flood warning and observing systems that can also be used for verification of rainfall and river levels. The Corps of Engineers reservoir regulation system provides valuable access to some information over an existing radio system. Local self-help forecasting and warning programs also can provide accurate and timely information on, or verification of, existing conditions. Communications systems independent of storm-vulnerable land lines should be developed to assure rapid assembly of needed information.

V. FORECAST PREPARATION

The time between heavy rainfall and flooding, determined usually by the size of the drainage area, topography and storm characteristics, determines the type of flood forecasting and warning system that can be used effectively. This chapter reviews how several different flood forecasting and warning systems operate and which NWS offices have responsibility for them. The flash flood warning system is used for areas where flooding can occur rapidly on small streams, while a basinwide river flood forecast and warning is used for main rivers and major tributaries. Self-help flood forecasting and warning systems operated by local organizations provide the capability of forecasts and warnings for areas not covered thoroughly by the National Weather Service.

Small Stream and Local Flooding

Flooding by streams is often called flash flooding because of the short time between the causative events such as heavy rainfall, dam or levee failure, or a sudden water release by an ice jam breakup which cause rapid rises in stream levels with consequent flooding of adjacent lands. The rapid short-term flooding of streets, underpasses or low-lying urban areas is caused by excessive surface runoff from heavy rain falling in a small, local drainage area.

Small area local flooding caused by flash floods, due to the nature and size of the drainage area, is beyond the effective coverage of the basinwide river forecast system. Meteorological and radar observations and rainfall predictions can provide some advanced information about the potential for flash flooding in local areas. Rapid dissemination of warnings and responsive action is necessary to deal effectively with flash flood situations. The NWS flash flood warning system operates separately from the river forecast system.

There are two different NWS offices which are responsible for weather forecasts and three different NWS offices which are responsible for flash flood watches and warnings. The larger Weather Service Forecast Offices (WSFO) serve part of a state or zone, and the smaller Weather Service Offices (WSO) serve a smaller several-county area. Weather radar stations are usually located at WSFO's or WSO's.

Weather Service Forecast Offices (WSFO's) normally issue twice daily weather forecasts up to 48 hours in advance, and an extended weather outlook up to five days in advance. They are also responsible for issuing flash flood watches in their forecast zone when conditions so warrant (see Figure 6). Prior to public issuance of the watch, alert or notice the WSFO will, if possible, consult with other sources including radar stations in the area of watch coverage. The MARFC is notified after a watch has been issued. In addition, a WSFO should issue flash flood warnings for counties within its forecast zone, if, for any reason, the appropriate WSO cannot issue the warning.

Weather Service Offices (WSO's) are responsible for local area weather forecasts and flash flood warnings for a several-county area. These weather forecasts are adaptations of the zone forecasts produced by WSFO's. The WSO also has the responsibility of notifying public action agencies and public dissemination media in their warning area that a flash flood watch has been issued by a WSFO and is in effect for a designated area. WSO's are also responsible for issuing public flash flood warnings for their county warning area. The nine WSO's county warning areas of responsibility in the Susquehanna River basin are shown in Figure 7.

Radar Stations form a basic network to maintain continuous electronic surveillance for their area of coverage. Offices with local warning radar generally maintain continuous surveillance, as manpower and other priority duties permit, whenever flash flooding is suspected or has been reported within 125 miles. Whenever a radar becomes inoperative, adjacent radar stations are informed and requested to provide continuous weather surveillance in the area normally covered by the inoperative radar. Radar station location and coverage in the Susquehanna River basin are shown in Figure 8.

The flash flood warning system organized to provide local warning from the nearest NWS office operates as follows:

Preliminary notification of the potential threat of flash flooding is sent from a WSFO to other NWS offices and selected key federal, state and local officials. This alerts them to developing hydrometeorological conditions. There is no public announcement of this condition since it is strictly for internal operations and to improve alertness and readiness to handle potential situations.

WSFO's (or radar stations when they detect very heavy rain) initiate coordination between the following NWS of-

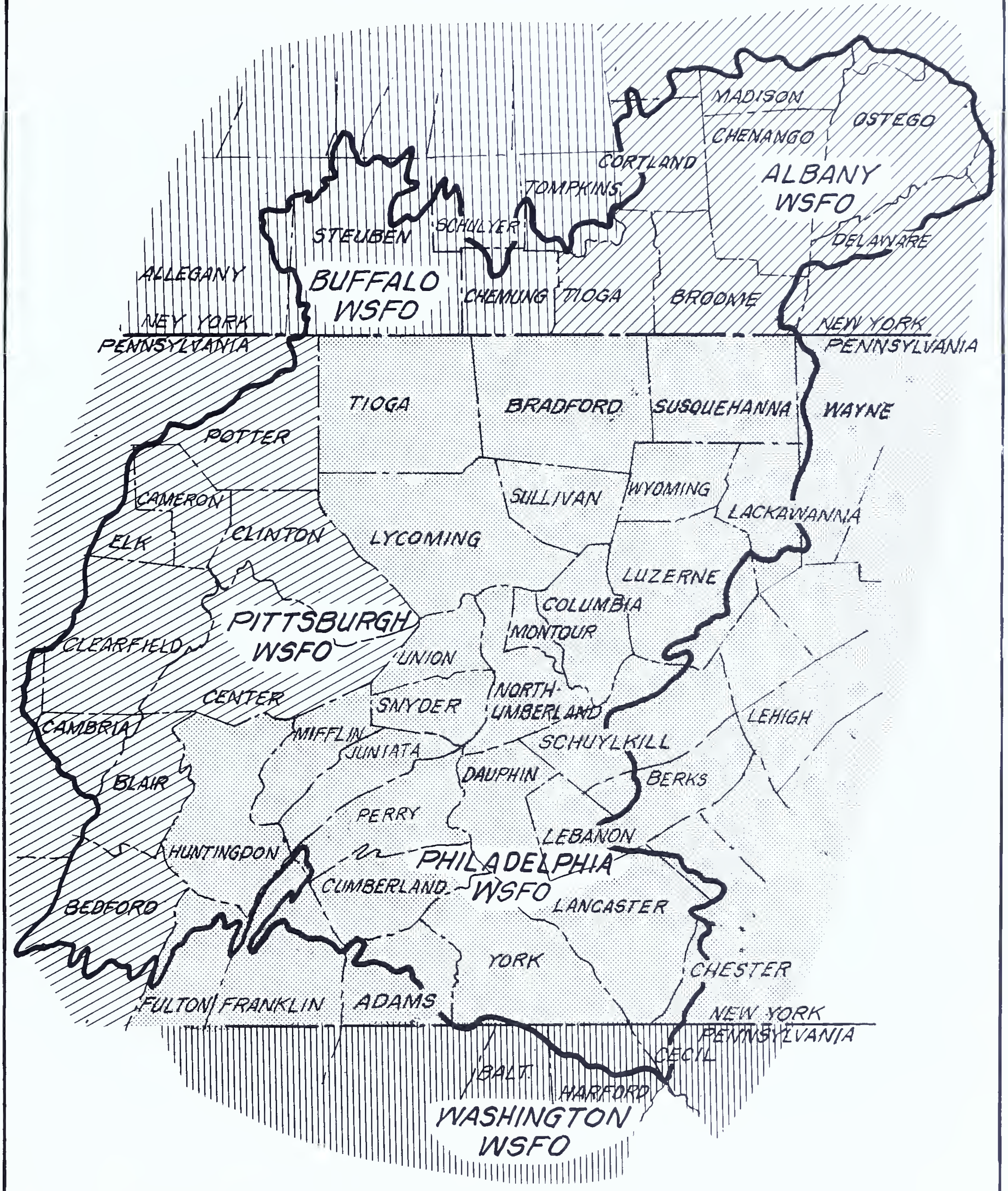

Figure 6. National Weather Service Zone Forecast Offices' Areas of Responsibility Covering the Susquehanna River Basin

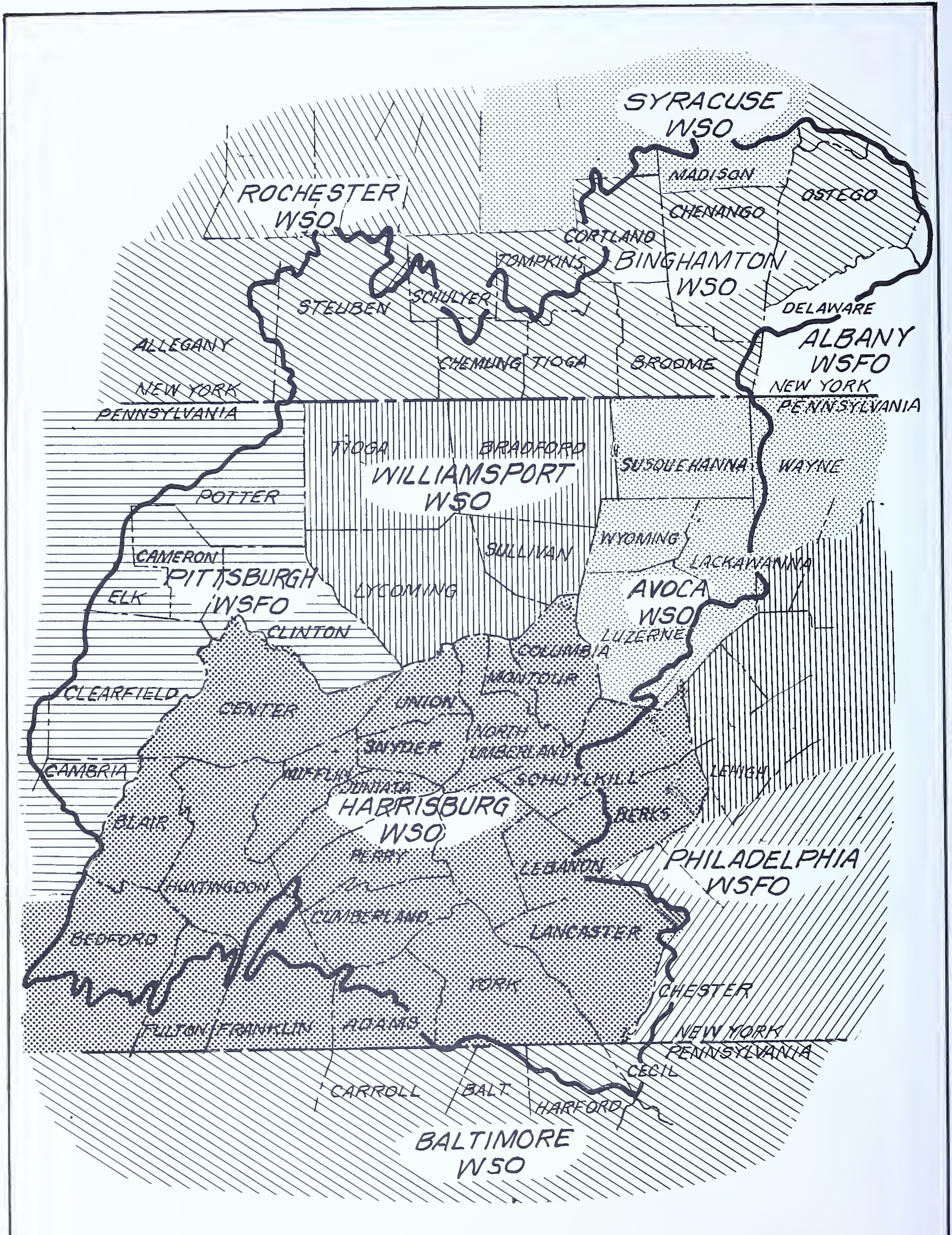

Figure 7. National Weather Service Offices' Local Forecast Areas in the Susquehanna River Basin

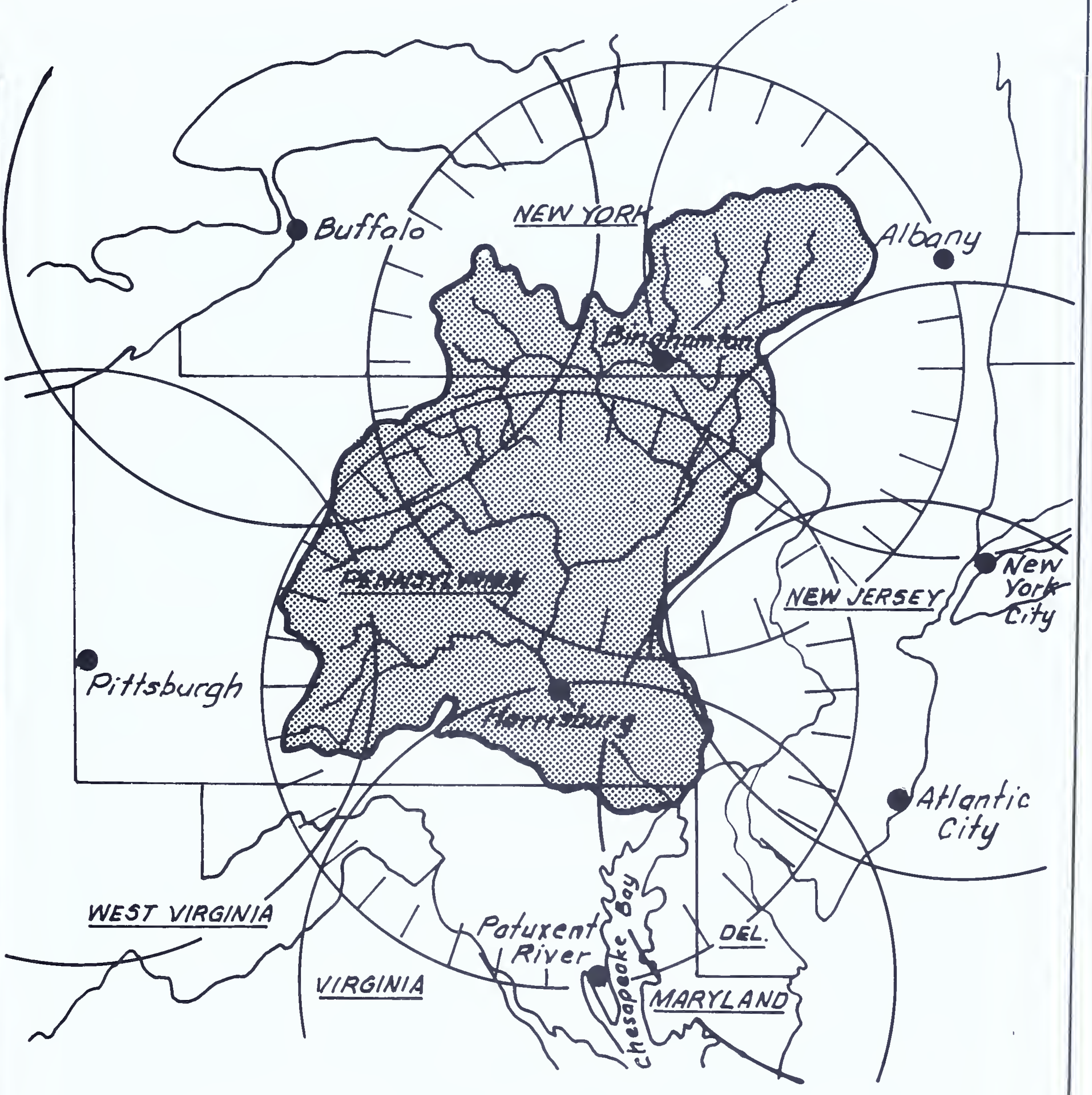

Figure 8. National Weather Service Radar Coverage in the Susquehanna River Basin

⌒ EXISTING RADAR STATIONS - Albany, Buffalo, Pittsburgh New York City, Atlantic City, Patuxent River

⌒ NEW RADAR STATIONS - Binghamton, Harrisburg fices to evaluate potential or existing flash flood conditions: 1) Weather Service Offices; 2) River Forecasting Centers; 3) radar stations; and 4) Quantitative Precipitation Branch in the National Meteorological Center.

Flash flood watches and warnings, therefore, are sometimes issued from three different NWS offices: WSFO's, WSO's and radar stations. This practice is used since it is essential that flash flood watches and warnings be issued publicly as soon as any NWS office identifies potential or actual rainfall conditions sufficient to cause flooding. There is often not enough time to route flash flood messages through other offices.

The MARFC's role in flash flood forecasting is to provide guidance on critical rainfall amounts. Three-hour rainfall amounts needed to produce minor flooding are transmitted daily to WSO's and WSFO's over the RAWARC circuit. Allowance for snow moisture content is made when necessary. In addition, twice weekly MARFC provides the RDO's with Headwater Statements necessary to bring streams up to one-half flood, flood, and twice flood flows. This allows the RDO to quickly assess the seriousness of a developing storm situation. Bi-weekly final index information is also supplied to self-help flood forecasting programs. The final index provides a guide to rainfall-runoff relationships which are used in the self-help forecasting procedures.

Flash Flood Messages

There are different types of flash flood messages used by the National Weather Service. The first, a preliminary notification of the threat of flash flooding, is an internal message sent from WSFO's to other NWS offices and selected Federal, State and local officials. This is not a public announcement. Public announcements are the Flash Flood Watch and the Flash Flood Warning. It is important to understand the meaning of these messages and the difference between them.

The Flash Flood Watch is the first public notification given. This message indicates that current developing hydrometeorological conditions might cause possible flash flooding in the general area designated. The preferred lead time is less than 12 hours between watch message issuance and the possible occurrence of flood-producing rains. This time factor is chosen because of meteorological uncertainty with longer lead time. People in the watch area should check preparedness requirements, keep informed, and be ready to take necessary action if a flash flood warning is issued or flooding is observed.

A Flash Flood Warning is a public message issued by the NWS for specific communities, streams, or areas where flash flooding is imminent or in progress. Persons in the warning area are thereby advised to take necessary precautions immediately. To be effective, in terms of public response to a flash flood warning, reports of flooding or heavy rainfall must be reliable. A flash flood watch is issued:

1) if flash flooding is reported;

2) if flash flood-producing precipitation is reported or is indicated by radar so that flash flooding is considered imminent; or

3) if reliable reports of ice jam break-up, dam/levee failure, or other causative events make flash flooding appear imminent.

To expedite the issuance of flash flood watches and warnings, and to insure that essential information is included, standard forms are used. This saves time by eliminating the necessity to compose a message format during an emergency.

Main Stem and Major Tributary River Forecasts

In contrast to the Flash Flood Warning Program, the River Flood Forecasting Program for the main stem and major tributary streams is a highly technical and complex process. The flow of a river fluctuates through a considerable range on an annual basis. It is characterized by rises, due to runoff from rainfall and snowmelt, followed by gradually receding flow. Flood forecasts are concerned primarily with predicting the time and stage of peak flows. Forecasts are also made for significant river stages expected at various times during the rising and falling periods.

There are three major steps to forecasting river rises resulting from a rainstorm and/or period of heavy snowmelt:

1) estimating the volume of water that will run directly off the land surface into the stream;

2) forecasting the distribution of this volume of water with time as it passes a forecast point; and

3) forecasting the change in shape of the floodwave as it moves downstream.

For the purposes of river flood forecasting and hydrologic analysis, a large river basin is divided into several smaller subbasins. Ideally, each subbasin should be homogeneous in its climatic and hydrologic properties, and should be small enough so that in any given weather situation factors such as precipitation, humidity, temperature, wind and sunshine will not vary too much across the area. The subbasin should also be fairly uniform with respect to soil type and vegetation.

A river gage must be at the mouth of each subbasin so that surface outflow can be measured. Since there is a practical limit on river gage placement, the set of subbasins that a forecaster works with is rarely ideal. It should also be obvious that ideal conditions seldom, if ever, exist for the innumerable variables or factors that are basic to forecasting.

Estimating Surface Runoff

When there is a storm, the first problem is to determine the amount of rain and/or snowmelt over a basin (read as subbasin). The mean rainfall for a basin can be calculated by simply taking the average of the rain gage readings from within the area. However, if the rain gages are not uniformly spaced, or if the catches of certain gages come under local terrain influences, then weights may be assigned to the gages so that a more realistic mean rainfall figure will be obtained. If there is snow on the ground, then the amount of snowmelt can be estimated based on air temperature, humidity, wind and sunshine.

Once the total liquid input of rain and/or snowmelt is known, the next step is to forecast the volume of water that will run into the stream. Many variables govern the amount of runoff that will occur and the physical processes are complex. A simple index, based on recent past rainfall, has been designed to represent the role of soil moisture conditions in the runoff process. This antecedent precipitation index is reduced by a small percentage each day indicating a drying of the soil. The reduction is usually in the neighborhood of 10 percent - depending on the basin. On days with rain, the mean rainfall over the basin is added to the antecedent precipitation index.

Due to seasonal changes in weather and consequent plant growth, there is also a seasonal change in the potential for evapotranspiration - water loss from the soil due to evaporation and transpiration by plants and trees. The antecedent precipitation index is therefore correlated with the week number of the year to refine the index to soil moisture conditions. Variations from the average seasonal potential for evapotranspiration can be accounted for by considering temperature, humidity, wind and sunshine as they are actually observed over the basin. This provides a further refinement to the index.

For a given amount of rainfall, a short intense storm will produce more runoff than a storm of longer duration. Storm duration is therefore correlated with the antecedent precipitation index and adjusted week number. A large number of past storms are studied and a rainfall-runoff relationship is developed. The final relationship is an "average" resulting from the consideration of many storm events. When the relationship is applied in a single forecast situation, some error in forecast runoff is to be expected. However, if the development of the rainfall runoff relationship was done carefully, the results will usually be satisfactory.

Forecasting the Flow at a Headwater Point

A hydrograph is a graphical plot of the flow rate (at a given stream location) against time. A unit hydrograph presents the result of one inch of runoff from a basin in a specified time period (Figure 9). The shape of a unit hydrograph depends largely on the shape of the basin, the slope of the land, the network of streams and drainage patterns within the basin, and the degree of manmade development. Past storms are studied to develop a unit hydrograph for each basin. Unit hydrograph theory states that the ordinates of the unit hydrograph are proportional to the runoff. For example, two inches of runoff would produce rates of flow twice as great as one inch of runoff in a given time period. For extended storms over a basin, the unit hydrograph (or the correct multiples of it) can be applied again and again, adding the results to obtain a complete hydrograph. To obtain a complete forecast hydrograph, surface runoff is added to the hydrograph that would have been observed had there been no storm or snowmelt.

Figure 9. Construction of Hydrograph from Complex Storm Using Simplified Triangular Unit Hydrographs

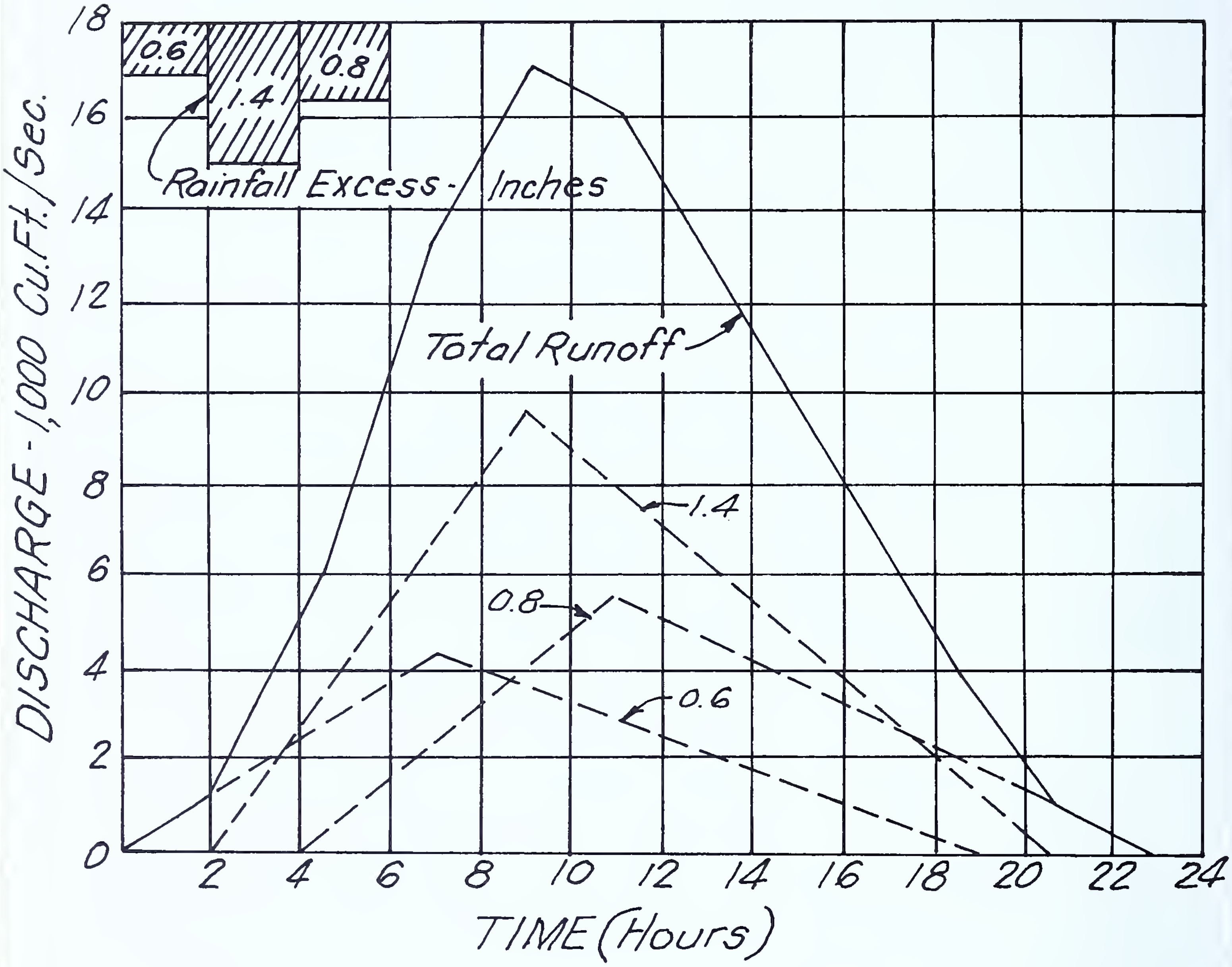

FIGURE 9
CONSTRUCTION OF HYDROGRAPH FROM COMPLEX STORM USING SIMPLIFIED TRIANGULAR UNIT HYDROGRAPHS

Once a peak flow is forecasted, it is converted to peak stage by using the rating for the location in question. A rating is the relationship between stage and flow and depends on such things as cross sectional area, roughness and slope of the channel. Ratings change over time, especially as a result of major storms. Ratings for most main stem locations in the Susquehanna basin are relatively stable while small streams are subject to more frequent rating changes.

Forecasting for Downstream Points

A forecast for a downstream point requires additional work to the above procedures for forecasting for a headwater forecast point (the most upstream forecast point). Runoff and unit hydrograph procedures are applied to the lower basin to get a forecast of the flow contributed from the downstream area. In addition, the volume of water from the headwater basin will also flow past the downstream point. This volume of water requires a certain amount of time to get to the downstream point. The hydrograph also changes shape as it moves downstream due to the characteristics of the channel and its flood plain. How a floodwave changes shape as it travels through a reach of the river is determined by studying past river rises. Finally, the flow routed from upstream is added to the runoff contribution from the lower basin to get a complete forecast for the downstream point.

Downstream forecasts are objective and are based purely on developed procedure. As the river begins to rise, observed river gage readings can be plotted against the forecast values. It will become apparent if initial runoff estimates are correct, and if not, adjustments can then be applied. Downstream points can also be forecast more accurately as upstream points crest, since observed flows instead of forecast flows, can then be routed downstream.

Forecasts for some points along the river are made by using crest relationships. Past river rises are studied for relationships indicating when upstream crest heights are followed by certain crest heights downstream. If the upstream point accounts for a large percentage of the drainage area of the downstream point, then the crest relationship will work well for storms of even distribution.

Forecasts can be made using the Quantitative Precipitation Forecast (QPF) or rainfall estimates obtained from facsimile machines and other sources rather than waiting until after the rain falls. These forecasts are approximate, but can be used as a guideline. Current studies are underway to try to improve the reliability of this service so that more accurate (reliable) flood forecasting can be issued with longer lead times.

Hydrologic Models

A commitment has been made by the National Weather Service to replace the index-type relationships with conceptual hydrologic models. This means that the physical processes in a basin will be represented mathematically. The use of conceptual models with a strong physical basis should lead to more accurate forecasts, especially for floods exceeding past experiences. Adoption and utilization of models also lays the groundwork for future improvement in a logical fashion.

Other routines, in addition to the soil moisture model, have been developed which will be integrated into the forecasting system. The snow accumulation and ablation model describes the build-up and subsequent melt of a snow cover. The channel routing routine provides hydraulic as well as hydrologic techniques to route flows through natural channels. There are also routines to compute mean areal values of precipitation, evapotranspiration and temperature.

The fitting of a conceptual model to a basin requires a large scale computer. The MARFC at Harrisburg now has a terminal to the National Weather Service IBM 360/195 in Washingto, DC. Data management routines that store, retrieve and manipulate data from direct access files have been developed. Work has begun, but it will require several years to change over completely to the model system.

Operational Forecasting

The Middle Atlantic River Forecast Center at Harrisburg has the responsibility of making the forecast for the Susquehanna River basin. It also has the responsibility of making forecasts for the Passaic-Raritan, Delaware, Potomac, Rappahannock and James River basins, an area extending from New York-New Jersey to North Carolina (see Figure 4 - MARFC's area of forecast responsibility).

A list of the sequence used in making river forecasts for the Susquehanna during flood siutations is presented in Table 5. The list indicates the approximate time that various jobs are finished. The timing is meant to reflect conditions during moderate flooding. The example sequence is idealized and does not reflect the impact on preparation time if an extraordinary storm such as Tropical Storm Agnes strikes. Some jobs might move along more quickly than indicated, and others sometimes take longer. Snowmelt can be a complicating and, therefore, a delaying factor. During major river rises, it also becomes necessary to recheck data, especially if several subbasins and their tributaries are in flooding conditions.

If the hardest hit areas are outside the Harrisburg RDO area, then operations at the Forecast Center can be carried out smoothly. However, if the storm hits hard in the Harrisburg RDO area of responsibility, the public service workload (phone calls and request for information) increases tremendously, and this extra work slows down the forecasting. This problem occurs because the RDO and RFC are staffed by the same people and function within the same office space.

Table 5

Typical Sequence of Events in Making a Flood Forecast

Time Job Is Finished	
8:00 a.m.	River and rainfall reports are received at MARFC.
8:05	River stages are converted to flow by manually consulting rating tables. The flow figures are entered on the master data sheet for the day and on work sheets that are used while running the forecast computer program.
8:15	Rainfall data is entered on the map for the day and on work sheets used for punching computer cards. Six-hour rainfall totals for eleven stations are entered on the map and on work sheets for punching computer cards. Temperature data (maximum, minimum and current) and snow data (depth on ground, amount of new snow and water equivalent of snow) are also entered on the map.

Time Job Is Finished	
8:15	Temperature, dewpoint, wind and sunshine data are collected for four stations. The antecedent evaporation index (a correction to week number) is computed for these stations.
8:20	Rainfall reports are punched on computer cards. Six-hour rainfall reports for eleven stations and antecedent evaporation indices for four stations are punched.
8:30	An initial run of the river forecast program is made. This program applies the runoff to the unit hydrographs and performs the hydrograph routing. A five-day hydrograph is generated for the forecast points included in the program. Hydrographs and routed flows for the main forecast points are plotted by hand.
9:45	The river forecast program is rerun with intervention by hydrologists to fit the observed river readings.
10:00	If more rain is expected during the next 24 hours, the forecast program is run again to include the expected additional runoff.
10:15	Crest relations are used to forecast intermediate points based on output of main forecast program.
10:30	Forecast messages are typed for dissemination.

The times indicated for public issuance of the forecasts are based on the morning data collection. During critical situations, a complete set of observations is also taken at 1:00 p.m., 7:00 p.m. and 1:00 a.m. Revised forecasts then would be ready for dissemination at about 4:30 p.m., 10:30 p.m. and 4:30 a.m. Table 6 lists river forecast points in the Susquehanna River basin and their respective RDO's.

Power failures at critical times have been a problem in the past for the MARFC because operational procedures rely heavily upon computer support. An emergency power generator has been installed and is operational at the

TABLE 6

SUSQUEHANNA BASIN RIVER FORECAST POINTS
Effective October 1976

Albany River District

	1	2	3
Susquehanna River			
Unadilla	x		
Bainbridge	x		
Conklin	x		
Binghamton			
Vestal	x		
Waverly	x		
Chenango River			
Sherburne			
Greene	x		
Chenango Forks	x		
Otselic River			
Cincinnatus			
Unadilla River			
Rockdale	x		

Buffalo River District

	1	2	3
Chemung River			
Corning			
Hickling Station			
Elmira			
Chemung	x		
Tioga River			
Lindley	x		
Erwins			
Canisteo River			
Addison			
West Cameron	x		
Cohocton River			
Bath			
Campbell	x		

Harrisburg River District

	1	2	3
Susquehanna River			
Towanda	x		x
Wilkes-Barre	x		x
Bloomsburg	x	x	
Danville	x	x	
Sunbury	x		x
Harrisburg	x		x
Marietta			
Tunkhannock Crk.			
Dixon	x		
West Branch			
Karthaus	x		
Sinnemahoning	x		
Renovo	x		
Lock Haven	x		
Beech Creek Sta.			
Cedar Run	x		
Camp Kline			
Jersey Shore	x	x	
Williamsport	x		x
Watsontown	x	x	
Milton	x	x	
Lewisburg	x		
Loyalsock	x		
Montoursville			
Trout Run	x		
Juniata River			
Saxton	x		
Williamsburg	x		
Huntingdon	x		
Mapleton	x		
Lewistown	x		
Newport	x		x
Lackawanna River			
Archbald			
Old Forge	x		

1/ Computer Forecasts: Daily forecast produced by computer. (The other forecast points require manual crest relation procedures and are processed only when necessary.)

2/ Computer Forecasts: Computer uses crest relations for indicated locations rather than unit hydrograph and routing methods. These forecasts are of better quality during peaking situations as opposed to flat uniform flow.

3/ Forecasts issued to the public daily by the flood forecasting service. The other points are publicly issued when necessary.

Federal Office Building, Harrisburg, Pa., in the event of similar experiences in the future. All other NWS offices having flood forecast responsibilities for the basin also have emergency power.

Self-Help Flood Forecasting Program

In an effort to provide local communities on moderate size tributaries and small streams with more precise forecasts (beyond watches and warnings), a local self-help flash flood warning program is sponsored on a cooperative basis by the Susquehanna River Basin Commission, the National Weather Service, the USGS, and state and local government groups. The program's goal is to enable local people to monitor and forecast stream flows in their areas. MARFC provides technical assistance in setting up the programs and bi-weekly forecasting guidance on soil moisture conditions known as the final index. When rainfall exceeds the critical value indicated by the final index, the system goes into full alert.

More information about this program is available in Susquehanna River Basin Commission Publication No. 42, "Planning Guide Self-Help Forecast and Warning System Swatara Creek Watershed, Pennsylvania," and No. 45, "Neighborhood Flash Flood Warning Program Manual."

Evaluation

The process used in preparing a flood forecast is, in most events satisfactory; however, missing data or delays in assembling data have been a problem in the past.

The capacity of NWS to do all that is required in preparing forecasts must be compared with the time between heavy rainfall and flood levels to evaluate the effectiveness of the forecasting process and the appropriateness of warning procedures. During widespread storms NWS staff is overwhelmed with work. Round-the-clock forecast operations are not normal, thereby limiting late night and early morning capability. They are instituted when conditions warrant; however, storms do occur late at night, therefore, some method of late night-early morning monitoring capability should be developed. Self-help flash flood warning programs may be a source of assistance to alert NWS staff to possible problems.

NWS staff capabilities during extensive storms combined with the capacity of equipment must be evaluated to determine system limitations. MARFC at Harrisburg and the RDO's at Buffalo and Albany are the key points in the forecasting process. Each of these offices has significant staff limitations during major storms. The time to assemble data, prepare, and disseminate a forecast can take as long as 12 hours after heavy rain has fallen. This factor should be considered in evaluating the system.

Rainfall observations are made every six hours. It takes one to one and one-half hours to assemble rainfall and river level data. Under ideal conditions about two and one-half hours are needed to complete a computer forecast and prepare it for dissemination. System delays can occur so another hour may be required. An additional three-hour time factor is included as a consideration for dissemination, unforeseen problems in data collection, assembly, forecast preparation, etc., or in other words, a time margin error. Disallowing the time margin error and assuming that everything runs perfectly in preparing a forecast, about three hours maximum warning time would be available in short lead time flooding (12 hour criteria) areas covered by the NWS river forecast and warning program. In areas with a more rapid response between heavy rainfall and excessive runoff with consequent flooding, obviously even less warning time is obtainable through a NWS forecast as the situation exists now. Therefore, in areas that have a potential of reaching beginning flood levels in less than 12 hours following heavy rain, alternative flood warning systems should be considered.

In addition, the capacity of the ADAS (automatic data assembly system) and the planned AFOS system must be evaluated to determine equipment and operation limitations, if any. Because of system and warning time, increased use of guidance information should be provided for the many self-help flood warning systems that are being organized to increase accuracy and timeliness of local forecasts.

The MARFC at Harrisburg provides forecasts for an area extending from New York and New Jersey to North Carolina. The Susquehanna River basin constitutes one-third of the area, but requires one-half of available staff time. When flood conditions develop throughout this forecast area, staff are overburdened with work. In addition, the MARFC office at Harrisburg has two responsibilities - one is providing a forecast for this multi-state area, and the second is serving as an RDO, which is responsible for disseminating the forecast for the Susquehanna basin area in Pennsylvania. Carrying out these two different jobs during a flood situation places additional burdens on existing staff.

Figure 10 shows forecast points at which MARFC provides a daily and computer forecast and the hours of time between heavy rain and near flood crest levels for those points. A comparison should be made in upstream areas between the time required to make and disseminate a forecast and the time between rain and the flood crest to determine the most practical forecast methods and procedures.

RDO's at Buffalo and Albany have one hydrologist available and responsible for assembling local rainfall and river level readings, transmitting the data to the MARFC, disseminating the forecast made by MARFC, and answering local requests for information. These offices also have available back-up forecast procedures, if needed; however, hand calculations are required to produce forecasts and forecast updates. The Albany and Buffalo RDO's also have to work with other River Forecast Centers in serving their assigned areas. Other NWS staff at the RDO, primarily responsible for weather forecasting, are supposed to assist the hydrologist. However, other duties may limit their back-up assistance for the hydrologist.

AFOS, Automation of Field Operations and Services, is being planned for all future NWS forecasting operations. This concept is based on the use of a giant communications network to link all NWS offices and the use of high speed computers to store and update data rapidly. In addition, cathode ray tubes (TV screens) will be used to display information so that forecasters can more quickly make forecasts. Mini-computers will be provided at many NWS offices for rapid display and updating of information. This system is not presently operational, and therefore, the impact of this system to improve the accuracy and speed of forecasting is not known. Also, it will be a few years before AFOS is installed and operational.

Improvements in meso-scale weather forecasting are not expected to provide enough accuracy to improve river forecasting. New methods of river forecasting based on scientific hydrologic models are being slowly implemented; however, they will take several years to be fully tested before being placed in full operation.

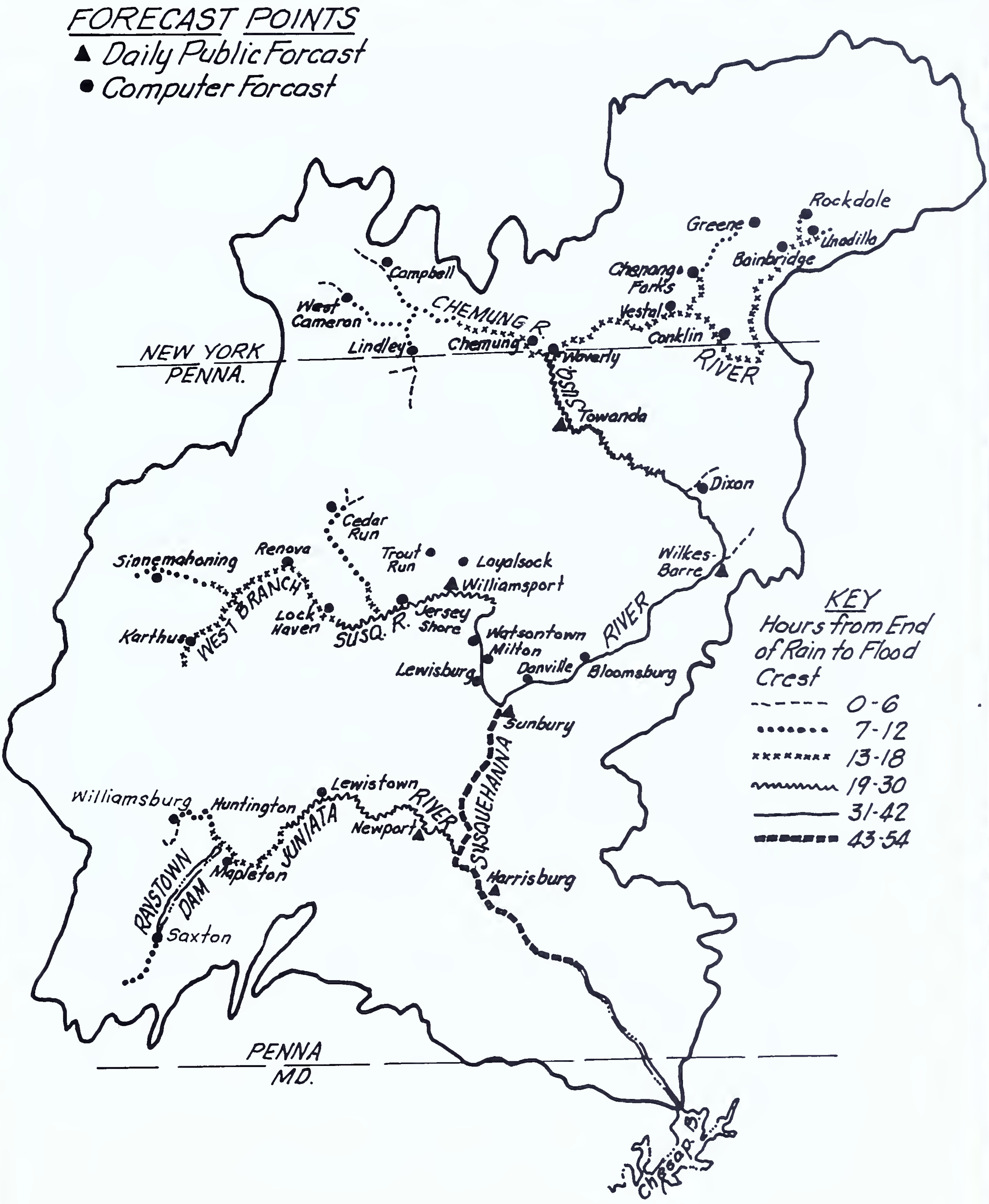

Figure 10. Hours from End of Rain to Near Flood Crests, and Forecast Points in the Susquehanna River Basin Flood Forecast System

VI. DISSEMINATING THE FORECAST

To be effective, a forecast must be disseminated quickly to the people who may be adversely affected by high water. Warnings must be early enough to allow for appropriate action to avoid possible loss of life and minimize property damage.

Many groups are involved in disseminating forecasts, as with other parts of the flood forecast and warning system. Each group has specific responsibilities and plays an important role in assuring that forecasts and warnings are disseminated properly. This chapter describes the role of NWS offices and how they interact during warning dissemination. There is also a brief description of the role of state and local organizations in flood warning dissemination.

Role of the Middle Atlantic River Forecast Center

As soon as the MARFC at Harrisburg prepares the forecast, it is disseminated to the River District Offices (RDO's) at Buffalo and Albany, New York. (See Figure 3.) A phone call is usually used to transmit river stage forecasts from the MARFC to RDO's.

The MARFC hydrologist will explain the basis for the forecast, indicating if any rain forecast for the next several hours has been included, how much snowmelt was used, and the degree of confidence in the forecast. If there is the possibility of more rain, a set of contingency forecasts may be issued to the RDO indicating river levels based on various amounts of anticipated or possible rainfall. The RDO is then able to present updated river information to the public as soon as rainfall reports become available.

Twice a week the MARFC provides the RDO's with Headwater Statements, the amount of rain necessary to bring streams up to one-half flood, flood, and twice flood flows. This allows the RDO to quickly assess the seriousness of a developing storm situation.

The Corps of Engineers in Baltimore, Maryland, is kept abreast of daily forecasts via a teletype in the River Forecast Center. River stage forecasts for Harrisburg are also included routinely on the daily radio weather broadcasts originating from the Harrisburg WSO. River stage forecasts for other locations are frequently included when significant rises or flooding are expected.

Role of River District Offices

The River District Offices (RDO's) are the public contact point in forecast and warning dissemination. They disseminate forecasts prepared by MARFC to state and local agencies and local public media.

The Harrisburg RDO (co-located with MARFC) serves the Pennsylvania portion of the Susquehanna River basin. The Buffalo RDO serves the Chemung River basin while the Albany RDO serves the North Branch of the Susquehanna River in New York.

The RDO disseminates the forecasts to the public via several different communication networks. The time and height of expected crests or any critical river stages for points in the RDO area are reported publicly. A statement indicating the significance of the expected rise is issued along with the stage forecasts.

Weather Service Offices (WSO's) at Williamsport and Avoca, Pennsylvania and Binghamton, New York also provide assistance in flood forecast dissemination when needed.

In addition to disseminating forecasts via the systems described below, many requests for river data and forecasts are received by phone from radio and television stations not tied into any of the established communications networks. As high water and flood conditions develop, the number of requests increase until all RDO phone lines are busy almost continuously. Radio stations frequently request on-the-spot taped or recorded messages while television stations periodically send camera and recording crews to interview NWS personnel for the latest appraisal and forecast of river and stream conditions throughout the Susquehanna River basin.

A limited phone warning list is also maintained by the RDO's for notification when river levels are expected to reach or exceed specified levels at designated places. In New York State,calls are made also by RDO's to the U.S. Geological Survey and the Flood Control Section of the New York Dept. of Environmental Conservation. The Harrisburg RDO makes calls to a very limited number of agencies and business firms as time and forecast workload permits.

Communications Networks Used in Flood Forecast Dissemination

RAWARC (Radar Report & Warning Coordination System) provides teletype information transfer between National Weather Service offices including the Regional Office at Garden City, Long Island, New York and National Headquarters in Silver Spring, Maryland. These administrative offices receive requests for information from members of Congress and other high-ranking officials during major floods.

NOAA Weather Wire is a 24-hour-a-day, Statewide teletype hook-up presently comprised of about 75 subscribers in the Pennsylvania circuit, and five subscribers in the Susquehanna basin in New York State. It includes NWS offices, other Federal and State offices (particularly the Pennsylvania State Council of Civil Defense, and the State Office of Disaster Preparedness at Albany, New York), radio and television stations, newspaper offices and public utility companies. The news media, of course, provide the greatest public distribution of forecasts and warnings.

The National Weather Service, as a public service, pays the long-line (telephone service) mileage cost into any community having a mass media subscriber, a daily newspaper, commercial radio station, or commercial or educational television station. The subscriber pays for the service installation cost for this information system. A subscriber leases a receive-only local channel teletypewriter and a control unit from the telephone company serving his community and pays also for teletype paper and ribbons. The cost per month will total less than $100.00 plus long line charges, if necessary.

A positive alerting device for the receiving teletypewriter is available. With this attachment, which is highly recommended, urgent watch and warning messages trigger an alarm bell and light on the teletypewriter, alerting receivers to the importance of the incoming message.

NAWAS (National Warning System) is a voice telephone communications system interconnecting all National Weather Service offices in Pennsylvania, all 13 Pennsylvania State Police troop headquarters and state and area civil defense headquarters. Forecasts and warnings can be readily dispatched to the above offices through a special phone at the Harrisburg RDO.

MARFC also has a NAWAS phone network with Civil Defense offices in all the northeastern and mid-Atlantic states as far south as Virginia, the River Forecast Center in Hartford, Connecticut and several military installations within the region.

NAWAS is used as the statewide forecast and warning dissemination system in New York State. It interconnects all six National Weather Service Offices, most city and county offices of Civil Defense, 73 county and city 24-hour warning points located in the sheriffs' offices, fire control centers or police stations, the state's six district Civil Defense headquarters, the New York State Police headquarters communications center and the State Civil Defense headquarters. All Weather Service offices, including the Albany and Buffalo RDO's can announce forecasts and warnings to all of the above locations through use of a special phone installed in each of their forecast centers.

The NAWAS system in New York is organized so that all counties and cities hear direct communications from the Weather Service offices. Most locations, however, cannot communicate directly back to the Weather Service offices and RDO's without having their messages repeated through a central point in the system. The three such points servicing the Susquehanna River basin are the NAWAS installation in Chemung, Broome and Onondaga Counties. These central or primary points, as they are called, are operated during normal working hours by the county civil defense staffs and in non-business hours by the 24-hour sheriff or fire control communications centers. County civil defense activate Emergency Operating Centers (EOC's) during emergencies. These centers serve as coordinating centers and a hub for all communications when fully equipped.

Their locations are:

Chemung County -- Civil Defense EOC in Horseheads and sheriff's office in Elmira

Broome County -- Civil Defense EOC and sheriff's office in Binghamton

Onondaga County -- Civil Defense EOC in Syracuse and Fire Control in Mattydale

NAWAS points in the Susquehanna River basin serviced by these primary points are:

Otsego County -- Fire Control Center in Oneonta

Schuyler County -- Civil Defense EOC and sheriff's office in Watkins Glen

Tioga County -- Civil Defense EOC and sheriff's office in Owego

Allegany County -- Civil Defense EOC and sheriff's office in Belmont

Steuben County -- Civil Defense EOC and Police Comm. Center in Bath

Cortland County -- Civil Defense EOC and sheriff's office in Cortland

Chenango County -- Civil Defense EOC and sheriff's office in Norwich

Operational procedures provide that any announcement over NAWAS will be acknowledged by those counties and cities for whom it is intended. These acknowledgements are made to the primary points and the primaries repeat all such acknowledgements to the state civil defense headquarters. Any office that does not acknowledge is called by telephone and has the message repeated to them. Some counties have a procedure whereby flood warnings or similar reports will be immediately transmitted over local communications networks and advisories issued to the media and local officials. Other counties lacking such procedures presently are considering adopting a similar course of action.

Pennsylvania Civil Defense Teletype Circuit - All river forecasts made by MARFC are sent on this circuit relaying the information to all 67 county civil defense directors, the three area directors and State headquarters.

Pennsylvania CLEAN (Commonwealth Law Enforcement Assistance Network) is comprised of about 225 outlets in Pennsylvania to State and local police offices, county emergency communications systems, FBI offices and the Bureau of Motor Vehicles. Flash flood warnings and flood stage warnings can be dispensed quickly by a phone call to the dispatcher located in the State Capitol. The warnings are relayed over a special communications network to law enforcement offices in the affected area of the State and are received almost instantaneously on TV-type monitors.

NOAA Weather Radio, an additional dissemination method, is gradually becoming operative in the basin. Under a January, 1975 White House policy statement, NOAA Weather Radio was designated the sole government-operated radio system to provide direct warnings into private homes for both natural disasters and nuclear attack. This capability is to supplement warnings by sirens and commercial radio and TV.

NOAA Weather Radio broadcasts are usually made on one of three high-band FM frequencies - 162.40, 162.475 or 162.55 megahertz (MH_Z). The 162.475 MH_Z frequency is used only in special cases where required to avoid channel interference. These frequencies are not found on the average home radio now in use. However, a number of radio manufacturers offer special weather radios to operate on these frequencies, with and without the emergency warning alarm. Also, there are now many radios on the market which offer standard AM/FM frequencies plus the so-called "weather band" as an added feature.

NOAA Weather Radio provides continuous, around-the-clock broadcasts of the latest weather information directly from National Weather Service offices. Taped weather messages are repeated every four to six minutes and are routinely revised every two to three hours, or more frequently if needed. Broadcasts can usually be heard as far as 40 miles from the antenna site, sometimes more. The effective range depends on many factors, particularly the height of the broadcasting antenna, terrain, quality of the receiver and type of receiving antenna.

Table 7 lists the broadcast sites in and around the basin and their scheduled installation dates. Figure 11 shows the estimated coverage within the river basin from each transmitter site.

Table 7

Sites for NOAA Weather Radio Transmitters and Installation Dates

Location	Installation
Binghamton, NY (Remote site at Elmira)	November 1978
Williamsport, PA	November 1978
Avoca, PA	November 1978
Harrisburg, PA	November 1978
Allentown, PA	November 1978
Philadelphia, PA	Completed
Hagerstown, MD (Broadcast from Washington/Baltimore)	January 1979
Clearfield, PA	November 1978
Blue Knob, PA	November 1978
Baltimore, MD	Completed

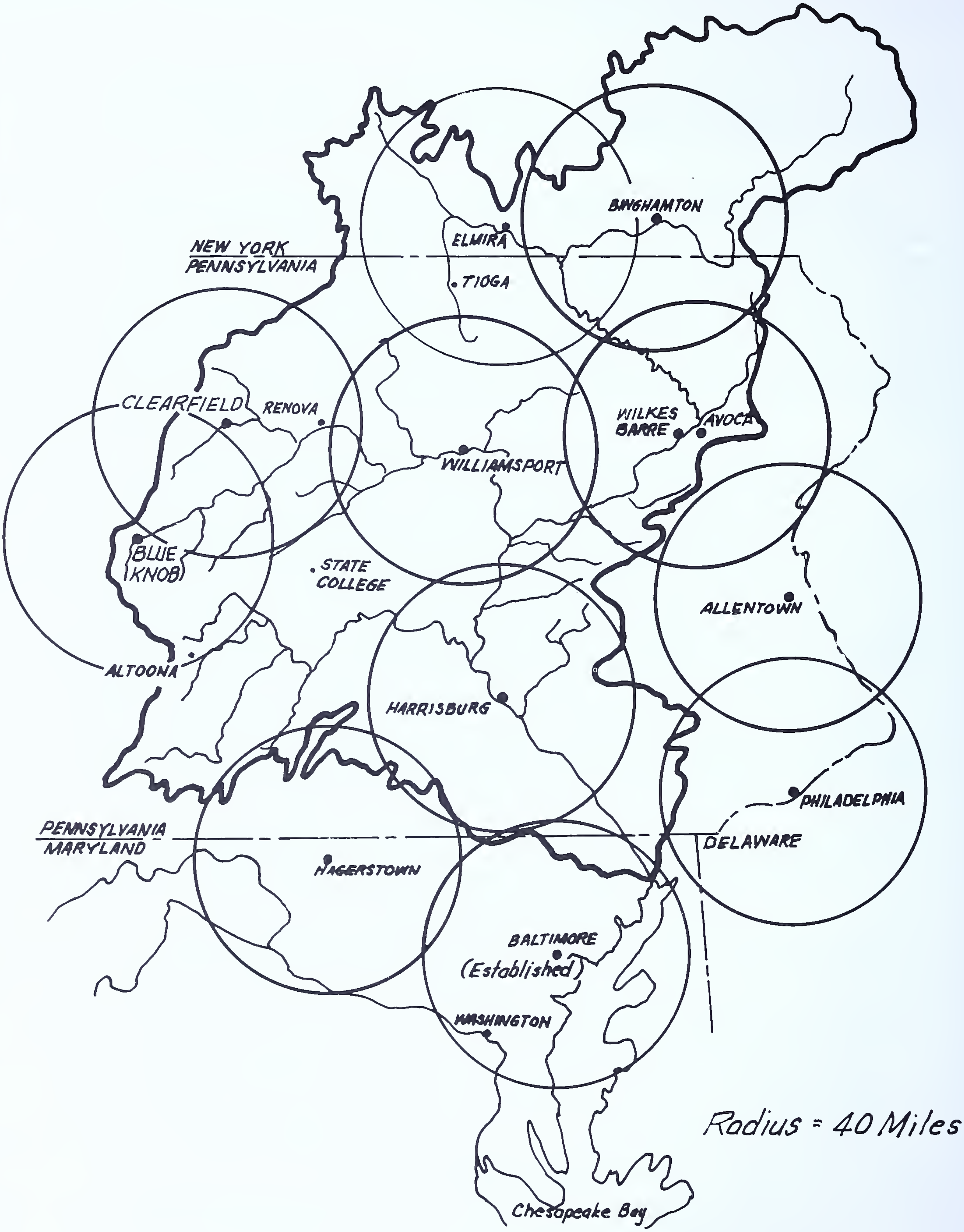

Figure 11. Estimated NOAA All-Weather Radio Coverage in the Susquehanna River Basin

12/76

Role of the State and County

States provide communications from RDO's to county and/or municipal offices having civil defense or emergency preparedness responsibilities. In addition, state civil defense or disaster preparedness agencies have the responsibility to provide the coordination and training necessary to carry out disaster preparedness actions.

County civil defense or emergency preparedness offices are the focal point between flood warning message transfer and action. The capability for coordination and communications is the determining factor in making the effective transfer of a flood warning message over a Statewide communications network to the community or municipality that needs the warning.

Counties with 24 hour-a-day communications centers have the greatest effective response capability to flood warnings. Some of these are emergency service headquarters such as sheriff, fire and police centers that incorporate communications for other local governmental services. In Pennsylvania, the State Council of Civil Defense operates several different statewide communications systems and can coordinate the use of others.

Evaluation

Dissemination Network

Improving the existing flood warning system requires conscious involvement of many different agencies and levels of government. Since this evaluation focuses primarily on the federal components of the system, a general evaluation only will be made of other levels of the system. However, it must be emphasized that the states play an important role in the coordination and operation of the non-Federal part of the system.

The existing system relies on the teletype and telephone, both land-line based systems susceptible to disruption in severe storms. The Corps of Engineers relies also on a radio system for its reservoir regulation system.

None of the existing communications systems can disseminate a forecast or warning in cases of telephone systems failure or overload. Existing state agency operated radio systems could be utilized; however, this has not been organized and coordinated effectively. There is a need to evaluate the use of an alternate radio and/or satellite based communications warning system. Such an emergency communications system should link together the National Weather Service, state agencies and county civil defense. Subbasin emergency communications networks, if properly coordinated, may be able to use existing radio equipment. There is need to coordinate emergency communications across state lines where river subbasins and larger watersheds flow from one state to another. Such coordination can be more effectively accomplished at the state level.

The existing basinwide warning dissemination system is a combination of separate sub-systems. Each of these sub-systems serves a group of agencies and different levels of government. Sub-system linkages may be time-consuming and often difficult to make during times of stress. Improvements in the forecast dissemination system are needed to enhance reaction activity and reduce the time between forecast/warnings and responses. Effectively integrating many governmental units at different geographic locations with varying responsibilities is a major challenge. Improved linkages will require integration with emphasis on how to provide rapid crossovers between the different parts. At the federal level, the National Weather Service, Corps of Engineers and Defense Civil Preparedness Agency have the responsibility. At the state level, disaster preparedness and civil defense agencies have the authority and responsibility to coordinate state agencies and link to county government. At the county level, county emergency preparedness agencies have the responsibility to coordinate and provide linkages to city and smaller government levels.

States play a crucial role in linking together the parts of the flood warning dissemination system. Here is a brief evaluation of related state operations.

Flood warnings and forecasts for Maryland communities along the Susquehanna River are not issued directly from MARFC, but are transferred through different National Weather Service Offices before reaching flood prone communities. Since flood levels are affected by the operations of the hydroelectric dams in the lower Susquehanna River power plant officials normally use the phone to inform local emergency preparedness officials about their operations. There is no radio communications between the power plants and local communities.

In New York State, total reliance is placed on the NAWAS telephone warning system. If this system becomes inoperable for any reason, there is no alternate way for dissemination. Only limited use is being made of the NOAA's Weather Wire teletype in the Susquehanna basin in New York State, and none of the existing teletype installations is linked operationally to either local or county civil defense. There is no NOAA Weather Wire service at any State or county office in the basin where there is someone on duty 24 hours-a-day.

New York State does not have emergency radio capability to disseminate flood warnings and forecasts to county or municipal civil defense organizations. Radio communications systems operated by different state agencies do not provide emergency communications between the state warning point at Albany and county warning points, or between county warning points, district disaster preparedness centers and regional or district offices of state agencies.

In New York State budgetary authorization has been obtained for the installation of radio communications systems which will expand the capability of emergency radio communications at civil defense district offices, by providing for the installation of radio communications on local government frequencies and the State Dept. of Transportation radio system. Future authorization is anticipated, in the next two years, that will provide radio equipment on the State Dept. of Environmental Conservation, the State Fire Service, and the State Police radio networks. When implemented, this equipment should enhance emergency communications and coordination capability at the district or regional level.

The state warning point at Albany is the coordinating point and the linking point for flood warnings and forecasts. This facility is not manned around-the-clock by State Office of Disaster Preparedness staff, but is manned by State police during off-duty hours.

In Pennsylvania, there is need for improved coordination and linkages of existing emergency radio systems, between county warning centers, state field operations, and NWS offices.

In addition to the problems identified in each state above, there is also the need for states to provide support and stimulus for improvements in emergency communications at the local county and community levels that will enhance the effectiveness of the local response. Some counties have adequate emergency communications equipment; however, in others, there is insufficient capability and/or poor coordination.

Public media, mainly radio and TV, play an important role in river flood forecast and warning dissemination. At times, however, the media display a general lack of understanding about the difference in meanings of flood warning messages and the local implications. In some locations, county civil defense has organized communications with radio and TV stations in which the county civil defense director can provide needed interpretation and authority to the warning message. There should be better coordination between county civil defense, local radio and TV and the NWS offices, about how to handle flood warnings.

Installation of the NOAA Weather Radio broadcast system will provide communications directly from NWS offices to 85 percent of the public in the basin, greatly improving flood forecast and warning dissemination. NOAA all-weather radio may not have sufficient coverage to reach all portions of the Susquehanna River basin, especially in upstream areas of the Susquehanna River in New York.

Warning Messages

There is a public confusion over the meaning and coverage of warning messages as now used by the National Weather Service. Messages should be more specific and relevant to local situations. The most effective message is one issued by a local authority which describes in detail what is happening, what is expected to happen and gives specific instructions to those affected. The National Weather Service does not have the capability to do this. However, increased knowledge and information at the local level could provide the basis for local civil defense to produce the added specific information and interpretation that is needed. Self-help flood warning systems are providing local civil defense with a much greater capability and understanding to more effectively do this job. These systems are limited to upstream headwater points and cannot be applied downstream where more complex forecast procedures must be used.

VII.CORPS OF ENGINEERS RESERVIOR REGULATIONS

Corps of Engineers' reservoirs in the Susquehanna River basin have sufficient storage to materially affect flood flows at many places. Reservoir discharge information is needed, therefore, in the preparation of a flood forecast. The Corps of Engineers has developed operating procedures for the control of basin reservoirs during flood periods. This chapter describes the procedures used by the Corps' Baltimore District, including the communications systems used in coordinating and managing reservoir regulation. Corps' reservoirs in the basin for which these procedures apply are described briefly in Appendix D.

Communications Used for Reservoir Regulation

The communication facilities used for reservoir regulation are the telephone, closed circuit teleprinter, teletypewriter (TWX), and a shortwave radio network. The District's Hydrology and Hydraulics section has a closed circuit teleprinter on the Maryland Weather Wire for area weather forecast data. A teletypewriter (TWX) connected with MARFC provides streamflow data. A teletype is also located in the Whitney Point maintenance office which receives data from the National Weather Service in Binghamton, New York and relays this information to the District Office. The TWX's are set on unattended service during nonduty hours for receiving messages. Initial notice by NWS of critical runoff or storm conditions during nonduty hours is made by telephone to DRCC personnel.

The initial alert procedures are designed to assure prompt notification to DRCC personnel of any imminent flood conditions regardless of regular business hours so that radio communications can be established before telephone lines become inoperable. The District radio communications network is designated as the Baltimore District Flood Emergency Net. The net consists of 17 fixed stations connecting the Baltimore District Office, River Forecast Center, flood control dams, and a number of mobile stations. The District headquarters can communicate with all mobile units in the District. This system is a unit of the radio emergency network of the Corps' North Atlantic Division.

During normal periods, radio drills are held daily at 8:15 a.m. and during flood alerts the net is operated as required. When the DRCC is activated on a 24-hour basis all stations monitor continuously.

In an emergency situation the initial alert from a dam operator to the District Reservoir Control Center (DRCC) in Baltimore will be by telephone. If communications fail, the dam operator will follow the emergency instructions established for that dam. He will continue his efforts to contact the DRCC by telephone or radio, radio relay through MARS or SEN amateur emergency nets, or the State Police radio net, if possible.

Amateur radio network organizations augment the District's communications system. The two principal ones within the pertinent area are MARS and SEN. The District radio station and the stations at the dams are members of the Military Affiliate Radio System (MARS) and the Susquehanna Emergency Net (SEN). The latter is a network of amateur operators in Maryland, Pennsylvania and New York organized to furnish data during flood emergencies.

In a flood emergency, instructions for operation of dam gates will be issued directly to each dam operator by Baltimore District Hydrology and Hydraulics section personnel assigned to the DRCC. Emergency operation without such instructions is authorized only in the event of a complete failure of all communication between the DRCC and the dams. Although highly improbable, should such a condition develop, there are several ways to re-establish communication. In the event that communication breakdown is due to failure of DRCC telephone and/or radio facilities, a hydrologist will be dispatched to the MARFC in Harrisburg, Pennsylvania, where communication will be re-established. In the interim, the dam operator is to rely on storm and flood data and forecasts, plus advice on request, from MARFC. In the event of a primary power failure and resultant loss of back-up communication with the DRCC, dam operators are to establish radio communication with each other and work perferably through Whitney Point maintenance office acting as network control. In this instance, each dam operator would have the benefit of storm and flood data available to the others. Also communication is to be established with the North Atlantic Division office and with the Susquehanna Emergency Net (SEN), most of whose members have auxiliary power available and would probably be operating for storm and flood data. With auxiliary power available and several radio communication sources, a dam operator would become completely isolated only through his own equipment failure.

Data Collection for Reservoir Regulation in the Basin

NWS rainfall and river data is a basic part of the Corps complementary data system for reservoir regulation. The

Corps collects data from some additional locations and they supply it to MARFC for use in preparing flood forecasts. The following data is used by the Corps in reservoir regulation.

Precipitation

There are at present 139 precipitation stations in the reporting network. (The locations, reporting agencies, and reporting criteria of these stations are shown in Appendix A.) Precipitation reports are assembled at the DRCC from District field personnel and from the MARFC, usually via TWX. Reports are sought from all stations in the network when flood conditions exist within the basin. During normal or nonflood conditions, reports from 84 stations are received daily regardless of precipitation; 55 stations report precipitation has fallen in a 24-hour period. Additional data can be obtained upon request to the MARFC in Harrisburg.

Streamflow

Seventy-six stations form the present reporting network on river stages to the DRCC (Appendix B). When requested, reports are obtained from dam operators for 24 stations near existing projects. The RDO's at Albany and Buffalo, New York transmit readings by the computer terminal system to the DRCC.

During normal or nonflood conditions 27 river stages are received daily from the MARFC, usually via teletype. During periods of flooding within the basin, reports from MARFC are regularly received on 52 stations at 6- or 12-hour intervals. Additional data, if required, can be obtained upon request to the MARFC.

Snow Surveys

Personnel at the reservoir projects conduct weekly snow surveys (during times of snow cover) in reservoir watersheds. Reports on depth of snow and water content for several stations in each watershed are forwarded by radio to the Hydrology and Hydraulics section and relayed to the MARFC via TWX. During times of critical runoff from snowmelt the surveys are made more frequently as requested by the DRCC.

Ice Conditions

Data regarding ice conditions at stream gages are included in information received from the MARFC reporting network. Special bulletins concerning ice movement, ice jams and resultant flood conditions are received from the MARFC when conditions warrant. In addition, District field personnel make ice reconnaissance surveys as required.

River Stage Forecasts

River stage forecasts issued by the MARFC are received in the DRCC during flood and nonflood conditions via TWX. During periods of flooding, river stage forecasts and crest stage forecasts at 12- and 24-hour intervals are usually received for most gaging stations listed in the reporting network as well as at other intermediate localities which are affected. Additional crest and river stage forecast information is issued by the MARFC as conditions warrant. During nonflood conditions, daily bulletins are received which include forecasts for several key gages for 7:00 a.m. of the following day.

Runoff Potential

Bulletins on potential runoff are received at the end of each week via TWX. The reports, which originate at the MARFC, include the calculated antecedent precipitation index (API) at Old Forge and Renovo, and also 12-hour rainfall amounts necessary to cause half-flood, flood and twice flood stages at several locations, as based on NWS flood stage levels. The API is a measure of current runoff potential in terms of soil moisture content. Other flood potential bulletins are received from the MARFC at more frequent intervals as flood conditions appear more imminent.

Precipitation Forecasts

Quantitative precipitation forecasts are received daily from the NWS over TWX. The forecasts are coded message forms describing the isohyetal pattern which is forecast to occur within the next 12- and 24-hour periods, and the following or second 24-hour period. Revised forecasts are issued when conditions warrant updating previous predictions.

Weather Data

Daily and five-day weather forecasts for state and zones, weather summaries and other meteorological data are received via the teleprinter. Advisory bulletins which detail the nature, scope and expected development of tropical storms and hurricanes are also received via the teleprinter as they are issued. Severe weather warnings are received from the NWS via teleprinter and are also received by telephone from First Army Headquarters.

Flood Forecasting Procedures for Reservoir Regulation

Predictions on storm runoff in terms of flood stage forecasts for key locations are received from the MARFC. These forecasts are relied upon to schedule reservoir regulation.

If, during an emergency, flood forecast data from MARFC is no available, the DRCC will forecast flood stages using district computer facilities. The existing software for flood forecasting is "Flood Forecasts - Upper Susquehanna River Basin, and Flood Forecasts - Lower Susquehanna River Basin." These programs contain all appropriate curves, constants, and flows necessary to forecast stages. Much of the procedure was supplied by the MARFC.

Expanded real-time, operational hydrologic models are being developed by the District.

Table 8 lists the sites for which the DRCC is capable of producing forecasts.

Table 8

Forecast Points by the Corps'
District Reservoir Control Center

Conklin, NY
Chenango Forks, NY
Vestal, NY
Waverly, NY
Lindley, NY
Addison, NY
Campbell, NY
Corning, NY
Chemung, NY
Towanda, PA
Old Forge, PA
Wilkes-Barre, PA
Danville, PA
Karthaus, PA
Sinnemahoning, PA
Renovo, PA
Williamsport, PA
Lewisburg, PA
Mapleton Depot, PA
Lewistown, PA
Newport, PA
Sunbury, PA
Harrisburg, PA
York, PA
York Indian Rock Dam, PA

The programs will be revised and upgraded as the District acquires remote print-out from the high speed computers in Vicksburg and Bethesda.

Flood inflows to reservoirs are forecast by using the appropriate seasonal curve for a nearby area and applying resultant runoff to the unit hydrograph for each reservoir. Correlation of the resultant unit hydrograph inflows and observed inflows for corresponding periods provides estimates of the expected inflow hydrograph. By considering the expected outflow at each reservoir, the peak reservoir stages can be predicted.

Reservoir Regulation for Flood Control

The plan of regulation, in general, is to avoid contributing reservoir discharges to stages downstream in excess of minor damage stages. This plan of regulation directs maximum utilization of available reservoir storage,but no attempt is made to reduce peak flood stages, if they are below minor damage. Allowance for a reasonable margin of error in forecasts results in some minor floods being reduced to slightly lower stages.

The regulation procedure for the reservoirs is based on the forecasting of stages at the pertinent damage centers. In addition to stage data at downstream damage centers, stages at stream gages located above most of the reservoirs will serve to indicate the magnitude of reservoir inflows. Gages located immediately below each dam, together with outlet rating curves will permit accurate determination of outlet discharges.

The DRCC keeps currently informed of potential flood conditions within the basin; and, in addition, the dam operators report flood and flood-producing conditions as required by the alert procedures outlined in the individual reservoir regulation manuals. Conditions for the initial alert for dam operators generally include the following:

(1) when predetermined river stages are forecasted;

(2) when ice jams occur at critical locations;

(3) occurrence of rainfall amounting to 0.5 to 1 inch in 12 hours or less at any station in the area; and

(4) any other condition which the dam operator believes is likely to require an initial alert preliminary to gage operations for flood control, including reservoir inflows exceeding designated amounts.

Following receipt of data by the DRCC indicating that flood conditions are imminent, communication schedules are established, and the reservoirs are regulated to affect downstream reductions of flood peaks. Regulation procedures for the reservoirs are based on the forecast of streamflow at the damage centers as issued by the NWS. In the event of communication failure with the NWS, the DRCC will make forecasts based on information available.

If an individual dam operator loses contact with the DRCC, closing of the gates will be based on data and forecasts available to the dam operator as described in the emergency instructions for that reservoir. Similarly, releases will be made by each dam operator according to the emergency instructions, which are based on following a recommended procedure utilizing available information.

In the event that a large, extremely rare, flood occurs which will cause spillway flow at the reservoir, the general procedure to be followed is the same for all reservoirs. As the gates remain closed for downstream flooding and the lake rises to near spillway crests, it may become necessary to start making minor releases in order to reduce the anticipated peak spillway flow. These releases are based on inflow and lake elevations. Inflows are calculated hourly, and the required releases indicated by the reservoir regulation curves are adjusted hourly as necessry. As the reservoir level starts receding, but while it remains above spillway crests, the gates are adjusted to maintain the maximum discharge which occurred during the flood. This discharge will be limited to downstream channel capacity when the lake is below spillway crests. If this discharge is less than channel capacity, it can be increased to downstream channel capacity as drawdown conditions permit. Drawdown to normal pool will be accomplished as quickly and as safely as possible.

VIII. LOCAL WARNING RESPONSE ACTION

The success or the benefits to be derived from a flood warning system depend on collective community and individual action taken to reduce the risks to life and property damage. Successful efforts are the result of pre-planned decision-making by county and community elected officials and trained and/or experienced professional staff given the authority and responsibility to direct and coordinate trained volunteers.

Essential Requirements for an Effective Local Response

Successful local flood warning actions are based on:

(1) Receiving a timely, accurate warning or basing decisions on predetermined river stage or crest levels.

(2) Understanding what a flood warning means or what predetermined flood levels or rainfall amounts will do.

(3) Knowledge of which areas will be affected by various flood levels.

(4) Having and using a tested plan so that effective decisions are made and action implemented efficiently.

(5) Designating decision-making authority and responsibility to an individual. The individual should have the experience and training to do the job.

(6) A clear designation of authority and responsibility between elected and paid professional staff so that there is no delay in decision-making.

(7) An Emergency Operating Center, EOC, or a communications center capable of providing leadership, coordination and radio communications to all affected areas.

Receiving Warnings

Each county should review its procedures for receiving forecasts and flood warnings and determine needs for improving warning time, warning reception, reliability and accuracy. Benefits from additional equipment or organizational methods should be evaluated.

Alternative criteria should be established which will provide emergency activation should warning systems break down or be in error. Example: a predetermined elevation or stage on an upstream river gage or two inches of rainfall in 12 or less hours are sufficient warning to activate a response.

Authority and Responsibility

The authority and responsibility for a local flood warning emergency action effort is often delegated to an elected official and a paid or volunteer leader. The person who has the authority and responsibility to make decisions and activate emergency efforts should be clearly identified.

Normally an elected official designates an individual to assume this responsibility. Along with the delegation of this authority should be a plan for initiating action. Predetermined threshold factors, such as a designated upstream flood level, or so many inches of rain in a specific time period should alert both the elected official and the appointed professional to initiate responsive action. If one or the other is absent or unavailable during an emergency, prior agreements should be implemented that will result in timely action being taken when it is needed. A program of phased action may be possible, such as: standby alert, partial activation, and full activation of emergency procedures.

Emergency Preparedness Plan

Each county and community subject to flooding should have an emergency preparedness plan. To be effective the plan needs frequent testing and updating. The plan should coordinate available manpower and equipment. A successful plan will result in essential coordination and pre-planned designation of responsibilities.

Communications Center

A key factor in successful emergency efforts at the local (county) level is an Emergency Operating Center or

Communications Center. This center should be out of the flood plain, have emergency power and be equipped with emergency communications equipment sufficient to link it with communities in its area of responsibility and to the state civil defense headquarters and the National Weather Service Office serving them.

Knowledge of Flood Experience

Knowledge of the effects of various flood levels on the community are essential. An understanding of what areas begin flooding first, what roads are closed early and which parts of the community are most subject to early flood damage are needed to make intelligent, timely decisions. The success or failure of community flood damage emergency actions are directly related to familiarity with what will happen during flood experiences, pre-planned personnel, the long-term support of elected officials and the necessary authority and responsibility vested in well-trained or experienced leadership.

Evaluation

State Programs

A preliminary review of the states' roles in flood damage reduction actions has been started to identify the most appropriate methods of developing an integrated flood warning system (and potential feasibility or eligibility for federal projects through cooperative or financial assistance or both).

Pennsylvania has invested substantial amounts of funding and organizational resources into the development of a well-organized statewide emergency action system. There is a clear designation of authority and responsibility. A statewide teletype system installed in all counties has improved communications. The State Council of Civil Defense is given authority, has the capability for coordinating state efforts and is providing needed training programs.

In New York State newly enacted Chapters 640 and 641 of the Laws of 1978 provide comprehensive revision and consolidation of the laws regarding State and local disaster planning. These laws will take effect April 1, 1979. The legislation establishes a State Disaster Preparedness Commission and authorizes the development and review of state and local disaster preparedness plans. The legislation provides for the direction and coordination of disaster operations.

However, flood warning communications and interagency coordination at the district or regional level needs review. In the Susquehanna basin in New York State there is no emergency radio systems to link district or area offices of state agencies and county warning centers. Improvements are planned. Budgetary authorization this year and anticipated authorization in the next two years should expand communications capabilities at the district or regional level if expected levels of funding are made available.

The State Office of Disaster Preparedness has been hampered by funding reductions which limit capability to equip and train county personnel in new programs.

County and Community Programs

In the time that this study has been underway it has not been possible to evaluate the efforts of all the hundreds of emergency action programs in communities throughout the basin. It has been possible, however, through work in several sample areas to identify some of the critical factors in local emergency action efforts.

The capabilities of the people and programs for flood warning and flood damage reduction at the state, county and local community is a reflection of interest, funding, priority emphasis provided by these different levels of government. There are many fine examples of emergency preparedness planning programs at the county and community levels. In others, however, there are no plans or they need updating badly.

Emergency communication capability has progressed rapidly since Tropical Storm Agnes in many counties and communities. The lessons learned about inadequate emergency communication have resulted in substantial improvement in some areas. In others, however, little if anything has been done. It is clear that coordination is needed for emergency actions. This can best be accomplished through a trouble-free radio system, operating from an emergency operating center. Each county in the Susquehanna River basin should be moving toward this goal. There are many counties that have 24-hour-a-day, 7-day-a-week communications centers which operate all radio systems in the county from one location. This is an efficient way to manage emergency communication needs.

There is a need to coordinate communications facilities in multi-county or county-state areas. Many of the recent improvements in radio communications facilities are focused on county needs. Statewide emergency radio coordination is needed for effective operations and coordination of different programs for different needs. Redundance is advisable, but full utilization of existing facilities may do much to meet needs.

There is a wide range of expertise, organization and support for emergency preparedness efforts at the county and community levels. The capabilities of the people and programs are a reflection of the degree of support provided by county and local government, and the amount of interest and concern expressed by local volunteers.

More support is needed by federal and state disaster preparedness organizations to provide training, emergency planning and simulation exercises to improve the readiness and capability of local disaster organizations. Increased federal and state funding and staffing devoted to natural prepraredness planning is needed. A combination of state and federal support is needed to develop subbasin emergency communicatins systems between NWS offices, state, county and community action agencies.

IX. FINDINGS AND RECOMMENDATIONS

This study has identified problem areas which must be solved before further improvement in the flood warning system in the Susquehanna River basin can take place. These problems or areas of need are:

(1) speeding up the river forecasting process;

(2) increasing the reliability of the river forecasting system;

(3) improving flash flood warning;

(4) improving local response; and

(5) providing ongoing review of the forecasting system.

The following sections of this chapter review findings in each of the above listed areas and make recommendations for future improvement of the system.

Accelerating the River Forecasting Process

Reducing the time required to produce a forecast will allow greater time for evacuation of people, goods and belongings thereby reducing flood damage losses. This study has determined that speeding up the time needed to make river forecasts is an area of major need requiring priority attention.

Findings

The existing river forecasting system is too slow to provide timely flood forecasts for upstream areas on main rivers. It sometimes takes over 6 hours to assemble data, transfer it to the forecast center, prepare a forecast and disseminate it. The reasons for this time lag are: (1) data are not collected rapidly enough; (2) delays in data transfer; and (3) during extensive/prolonged storms there is a lack of hydrology staff personnel at forecast centers. The MARFC is staffed to provide one full shift of coverage Monday to Friday. Additional coverage is met through use of overtime.

Automatic gages provide the most rapid method of collecting telemetering information. The existing pattern of automatic telemetering precipitation gages is not dense enough to detect flood producing rainfall in enough locations to produce a rapid river flood forecast. Observer reports are currently used to fill in these gaps and data collection is delayed because it takes longer to receive and transfer observer reports.

Snowmelt runoff is difficult to evaluate because existing snow survey stations are located in the valleys and do not accurately indicate average snow depth and water content. A more accurate and representative system of determining snowmelt runoff is needed.

River stage information provided by automatic telemetering gages is also used in making river forecasts. The existing river gaging system is adequate for most needs; however, it is essential that there be early detection of high river flows in some upstream locations. There are several areas (mainly in New York) where there are no public reference staff gages to obtain emergency river gage readings when automatic equipment is not working.

Data collection depends on facilities at several widely dispersed locations, some of which are located far out of the basin (Dayton, Ohio and Albany and Buffalo, N.Y.). These dispersed offices have other river basins to be concerned about and sometimes cannot devote sufficient time to the Susquehanna basin. In addition, the long distances involve complicate emergency communications.

Collection and transfer of data from data collection points to MARFC is often slow. ADAS, the Automatic Data Acquisition System, is too slow and can be restricted at times by other uses of the system to collect upper air computer runs. At some data collection points data transfer is done manually between different communication systems, a slow and cumbersome procedure.

During extensive storms, hydrologists (flood forecast personnel) at NWS offices become overburdened with work resulting in delays and slowing down of forecast preparation. This is especially a problem at the National Weather Service Office at Harrisburg which is a co-located office (Weather Service Office, River Forecast Center and River District Office). That is, the same staff and equipment are responsible for several jobs; river forecast preparation for a multi-state area, flood forecast dissemination for the Pennsylvania portion of the basin, and weather forecast dissemination for a multi-county area in

Central Pennsylvania. During major or extensive storms, data collection and forecast dissemination can delay forecast preparation.

Recommendations

Following are recommendations for accelerating the river forecast process:

1. Organize and implement more balanced and redundant precipitation reporting system that will permit more rapid evaluation of rainfall runoff. Specific location of recommended equipment is shown in Appendix E and summarized as follows:

   a. Installation of automatic telemetering rain gages at 48 locations.

   b. Adding automatic telemetering rain gages at 12 existing locations.

   c. Adding satellite data collection platforms at 33 locations to provide an alternate method of obtaining rainfall data.

   d. Add snow survey stations at representative monitoring locations at varying elevations.

   e. Install an automated receive station or "drop" for rainfall data at a central communications point with 24-hour coverage in each subbasin.

2. Install new river gages with telemetering capability at the following locations:

   a. Susquehanna River vicinity of Oneonta, NY

   b. Susquehanna River below Bainbridge, NY

   c. W. Br. Susquehanna River vicinity of Clearfield, PA

   d. Ouleout Creek above Sidney Reservoir, Franklin, NY

   e. Crooked Creek above Hammond Reservoir, PA

f. First Fork, Sinnemahoning Crk. above George B. Stevenson Reservoir, PA

g. Pine Creek vicinity of Waterville, PA

h. Juniata River vicinity of Lewistown, PA

i. Canisteo River vicinity of Addison, NY

j. Add new telemetering equipment to the recording gage on the Tioughnioga River at Cortland, NY, and complete an evaluation of all stations to determine where old or slow telemetering equipment needs replacement.

3. Install back-up public reference river staff gages at all river gaging stations used in the river forecasting system as both a method for local communities to obtain needed information and as a source of information during gage or communications breakdowns. There is a critical need in New York State for this equipment. A maintenance program for these gages will be required to maintain system integrity.

4. Consolidate data collection points and accelerate data assembly and transfer so that all automatic gage readings can be received at MARFC in 15 minutes upon demand. To accomplish this, it is recommended that data assembly and forecast dissemination functions in New York State portions of the Susquehanna River basin now performed at Albany and Buffalo, NY be transferred to the Binghamton WSO*. Expanded staffing and sufficient equipment and communications capability is necessary to do this job. Acoustic couplers and additional phone lines will be required for rapid data collection and transfer.

5. Separate the co-located River Forecast Center and River District Office at Harrisburg to reduce interference and delay in forecast preparation. Additional staff will be needed to implement this separation.

Increased Reliability of the River Forecast System

During major storms, breakdowns in the river forecast system have occurred. Many improvements have been made but there remain parts of the system which are subject to breakdown or failure. This section identifies these limitations and makes recommendations for improvements.

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* The Silver Springs office of the NWS commented that this is one approach to meet this objective.

Findings

The most serious deficiency is the failure of the telephone communications system and its disruptive effect on the river forecast system. Data assembly, data transfer and forecast dissemination are dependent on the telephone system and therefore subject to breakdowns at critical times.

To better evaluate this aspect of the flood warning system, a separate review of the flood forecast and warning communication system was undertaken as part of this study. This review made general comparisons of the existing system with other communications systems. It identified that alternative communications systems such as meteor burst, microwave radio and satellite communications systems have justification for additional investigation. Subsequent review of other studies revealed that meteor burst, commercial satellite and government-owned satellite are becoming cost competitive with existing data collection systems.

An alternate satellite data collection system is now being tested. Hourly river gage readings are being obtained by the Harrisburg River Forecast Center with real time delays of up to 3 hours (see Appendix C). There are, however, potential problems with the system. The satellite receiving antennae at Wallops Island, Va. must be protected when winds are expected to exceed 60 miles per hour and communications of data to Harrisburg over telephone lines may be subject to weather interference.

This test has shown that data collection over a satellite system is feasible, however, detailed cost evaluations have not been completed at this time. There are also test programs of the satellite and meteor burst systems in other parts of the country which are currently underway.

The Corps of Engineers radio system offers a back-up system for assembling some data. It is not possible, however, to add a great number of locations to the existing system. The greatest need is to provide back-up emergency communications between National Weather Service offices serving the basin and Corps of Engineers dam operators and reservoir control offices.

Susquehanna River forecasts are produced using a NWS computer facility at Suitland, Md. with interconnections at a computer terminal at MARFC. There is no back-up computer and delays have been caused by computer shutdown at Suitland.

National Weather Service RFC's and RDO's responsible for the river forecasting system become overwhelmed with work during major storms. If the storm lasts for several days, staff cannot properly perform their jobs, and the large numbers of requests from the public and other agencies place additional pressures on available time, often delaying forecasts and disrupting forecast updates.

Forecast dissemination is also subject to disruption with failure of the telephone system. There is no alternate emergency communications system for forecast dissemination. Pennsylvania has installed a statewide teletype system for forecast dissemination; however, this is land line dependent. In New York, the NAWAS telephone based phone system is also a land line system. There is no radio system organized for forecast dissemination basinwide. There are, however, radio systems of state agencies which provide partial coverage for forecast dissemination.

Major improvements in the forecast dissemination system are needed for more rapid and reliable transfers of forecasts between forecasters and users. Alternate emergency communication systems, which do not rely on the telephone, are needed from forecast points to all flood prone communities.

Evaluation of the feasibility of the use of satellite or other communications systems needs to be done to determine its applicability for forecast dissemination. This study has not identified sufficient information to determine the practicality of using alternate systems for anything other than data collection.

The National Weather Service is planning or has installed NOAA all-weather radio stations which are located to reach a high percentage of the public in the basin. However, if the transfer of forecast information to these transmitter locations is over land line telephone communications, it will be subject to interruption.

Improvements in disseminating the forecast and integration of forecast efforts between those who forecast and those who take action has many potential benefits in flood damage reduction. Including forecast dissemination as part of a package of warning-action-response, rather than as a separate unrelated component of the forecast system, will improve system performance and reliability. Development of alternative forecast methods, coordination of the dissemination system, and more careful linking of the forecast system with action agency users at the county and community level will strengthen the overall system.

States play a crucial role in the coordination of the flood warning system and the integration of the Federal program to local community needs. Only through carefully planned and tested efforts will a flood forecast produced by the National Weather Service be transferred to the flood prone community that needs it. The states play a crucial role in insuring that a speedy and reliable forecast transfer system is operating.

Recommendations

1. Conduct a more detailed evaluation of the costs and performance capability of satellite and other communications systems. Include a detailed analysis of an expanded satellite system including installation of an antennae at the Harrisburg River Forecast Center which will enable it to obtain data directly from the satellite, and a back-up receive site far from the Susquehanna River basin that would not be affected by the same weather system. Addition of a weather secure phone line from the remote receive site to Harrisburg will be needed.

2. Provide radio receivers on the Corps emergency radio net at National Weather Service offices at Binghamton, NY, Avoca, PA and Williamsport, PA.

3. Provide the Harrisburg River Forecast Center with its own computer capable of making operational forecasts, allowing the computer at Suitland, MD to be used for research and development and as a standby for forecasting.

4. Strengthen the National Weather Service overall hydrologic forecasting program. Increased hydrologic staffing at all offices with either data collection, forecast preparation or forecast dissemination responsibilities will do much to meet this need. The meteorologist-in-charge of NWS offices can provide more assistance to hydrologic data collection and flood forecasting by shifting workloads and staff coordination.

Organize emergency operating procedures for each NWS office having flood forecast responsibilities. During a flood emergency all NWS staff should assume priority assignments to produce a flood forecast. A program of backup support from other agencies can provide additional assistance.

5. Establish a basinwide system of forecast dissemination which does not rely on telephone communications systems. Evaluate satellite or other communications systems

in terms of the costs and feasibility for data assembly (Recommendation #1) and forecast dissemination.

6. Evaluate the performance capability of existing warning dissemination systems to determine potential disruption and failure during storms. Determine radio capability and implement a system that enables rapid and efficient linking of existing radio systems.

7. Review county and community emergency communication needs. Provide federal and state assistance where improvements are needed. Establish emergency communications between National Weather Service offices, field offices of state agencies, Corps of Engineers reservoirs and county emergency centers.

8. Improve coordination between county civil defense and public media. Establish direct radio communications between county emergency centers and mass media stations for warning dissemination.

Improved Flash Flood Warning

Flash flooding is a common occurrence in the Susquehanna River basin. Some areas experience flash flood damage almost each year.

This section identifies problems in flash flood warning and recommends an alternative procedure for improvement.

Findings

The existing flash flood "watch" provided by the National Weather Service provides adequate advance notification of possible flash flooding. However, the NWS "flash flood warning", notification of flash floods occurring, is often too late to be of value in protecting lives and reducing property damage. It, therefore, is the conclusion of this study that the most effective warning system for flash flooding is a warning system operated at the local level where rainfall observations key local flood damage reduction actions.

The techniques and operational procedures are available for locally operated flash flood warning systems. Susquehanna River Basin Commission Publication No. 42, "Planning Guide Self-Help Forecast and Warning System Swatara Creek Watershed, Pennsylvania" and No. 45, "Neighborhood Flash Flood Warning Program Manual" detail the organizational methods and procedures to use in local flood warning programs. In addition, the National Weather Service provides technical manuals for local flood warning use. What is needed to put these programs into operation is local leadership and operational coordination. County emergency preparedness staff are in the best position to provide the leadership and authority to get these programs operational.

Each county should make provision for a person or persons with professional training and experience in the technical and planning fields.

Recommendations

1. National Weather Service provide leadership for the development of self-help and flash flood warning procedures. The Corps of Engineers, Soil Conservation Service, Susquehanna River Basin Commission, Federal Disaster Assistance Administration and state agencies should assist.

Expand the National Weather Service program of technical and organizational assistance to communities in flood warning planning through the employment of at least two "Community Preparedness Staff" in the Susquehanna River basin.

2. State emergency preparedness agency assume leadership in coordinating and supporting local flood warning programs. This support should include training, funding and organizational assistance at the county and community levels.

3. County government, with technical support by federal and state agencies, assume the responsibility of providing flash flood warning for areas that flood in less than 12 hours following heavy rainfall.

Improving Local Response

Response to a flood warning is determined by the actions of individuals and groups or organizations at the local community level. The most effective actions that result in saved lives and reduced damages are those that are the result of pre-planned organized efforts by a coordinated community effort. This section identifies problems and weaknesses in local performance and makes recommendations to federal and state, county and community levels of government for the most effective support and improvement of these actions.

Findings

This study has identified that flood warning and damage reduction actions at the local community level have received too little support in the past. Assistance provided to the community is often a minor part of state or county government programs.

Improvements in the development of alternative forecast methods, coordination of the forecast system and more careful linking of forecast dissemination with action agency users at the county and community level will do much to improve the performance of the system. The system should be designed as a package of warning-action-response.

The complex warning system described in previous sections of this report relates for the main part to large main stream communities. It often does not consider adequately the particular concerns and needs of communities on smaller streams.

There are pre-flood disaster plans for a few communities; however, there are many others which have done no planning or plans are in need of updating. In almost every flood prone community many benefits could be attained through detailed evacuation planning that consider various flood levels. The disaster planning which federal and state agencies have carried out has provided generalized planning assistance related to nuclear attack and statewide disaster operational plans but with only limited assistance for community pre-flood disaster plans. Federal and state agency support of pre-disaster planning at the community level would result in many benefits from reduced flood damages and saved lives.

Findings -- Federal Government

A consistent consolidated federal disaster preparedness policy and program must be developed that support dual purpose natural and man-made disaster preparedness. Federal programs should be coordinated and oriented toward improving total disaster preparedness of county and local government. Federal financial support is needed to provide the planning, organizational structure, emergency communications capability and training to meet this objective.

Recommendations for Federal Agencies

1. Establish a coordinated federal program of total disaster preparedness that supports state efforts devoted to organization, training, program development and emergency communications at the regional, county and local government levels.

2. Organize a coordinated federal-state pre-flood planning unit which provides a community service program that translates technical flood plain studies and other hydrologic information into data that can be used for organization of evacuation and flood damage mitigation planning.

3. Expand National Weather Service assistance to communities by employment of at least two "Community Preparedness Staff" in the Susquehanna River basin.

4. Implement a program of total disaster preparedness by designating federal staff to work under the leadership of state emergency preparedness agencies.

Findings -- State Government

The amount of leadership, funding and coordination provided at the state level determines the effectiveness of local programs. States must assume a responsibility for integrating federal and state support with county and community needs. States should advocate increased responsibility and improved county and community capability in disaster preparedness programs. A continuing program of training and testing operational capability for disaster warnings and actions will be needed.

States need to evaluate the performance capability of existing warning dissemination systems during major storms to determine potential of disruption and failure of the system. This review should evaluate the capability of emergency radio systems to disseminate forecasts and warnings to all flood prone communities and determine the most rapid and efficient method of coordinating and linking emergency radio systems. County and community emergency communications needs should be determined and appropriate federal and state funding programs implemented to assist in the development of improved systems.

New York State Findings

The newly enacted Chapters 640 and 641 of the Laws of 1978 provide for the creation of a State Disaster Preparedness Commission with specific powers and responsibilities. This comprehensive legislation provides the authority for coordination of state agencies and authorizes the development of local disaster preparedness plans. The effectiveness of this new legislation on improvements in natural disaster preparedness will be dependent on subsequent budget support.

The Office of Disaster Preparedness operates a state command center. During off-duty hours this center is operated by state police. The command center serves as a focal point for state level emergency operations.

New York operates a statewide emergency telephone warning system, NAWAS. Since this system is a land line telephone system,there are limitations to its use when storms can disrupt its operations. Radio systems of several state agencies can be used for limited emergency communications; however, there is no statewide coordinated radio system. In the Susquehanna River basin in New York only partial emergency radio capability presently exists since the state command center, some area centers, regional or district offices of state agencies and county emergency centers do not have radio contact. If authorized and planned funding is provided for expansion of emergency radio systems, emergency communications and coordination between regional or district offices and county and community action agencies should be improved.

Training programs supported by the Defense Civil Preparedness Agency have been provided to maintain and upgrade skills of county and local government officials in emergency preparedness. State staff capacity to mount new training programs is limited by staff and financial restrictions.

Recommendations for New York

1. The comprehensive legislation,recently enacted in New York State,provides an opportunity for improvements in its natural disaster preparedness program. The legislation provides a basis for continuing coordination and emphasis on natural disaster preparedness. Sufficient funding and staffing allocations are necessary to implement needed programs.

2. Improve coordination of area or district emergency efforts through proposed radio communications systems. The effectiveness of new systems should be evaluated following installation. Increased state support for county communications systems is necessary to improve the capabilities of local government.

3. The newly created State Disaster Preparedness Commission, which will become effective April 1, 1979, has the authority to integrate federal and state resources into an aggressive program of support and training for flood warning actions at the county and community level. State funding and staffing is necessary for program implementation.

Pennsylvania Findings

Pennsylvania has taken a strong leadership position in disaster preparedness activities. Coordination at the state level is performed through the State Council of Civil Defense. There are ongoing training programs and organizational support for county programs. The State Council of Civil Defense operates a 24-hour-a-day communications center which also serves as a state command post during emergencies. The communications center provides a focal point for emergency communications facilities at the state level.

Training programs have been provided to maintain and upgrade skills of county and local government officials in emergency preparedness. A recent training program for county civil defense directors emphasized needs in flash flood warning actions.

The State Council of Civil Defense operates a teletype communications system to all counties. This system is a land line telephone system and is subject to disruption during storms. Emergency radio communications is possible through the use of radio systems operated by several different state agencies.

Recommendations for Pennsylvania

1. Continue and expand state leadership and support for county prediaster flood planning.

2. Evaluate the capability of emergency radio systems to link National Weather Service offices, area and county emergency centers and Corps of Engineers reservoirs. Organize and support subbasin and county communication systems.

3. Continue the State Council of Civil Defense program to increase county civil defense capability for flash flood warning.

Maryland Findings

The State of Maryland has a state disaster plan, as do Cecil and Harford Counties. National Weather Service Susquehanna River forecasts for Maryland communities are transferred through several different offices before reaching local agencies. Conowingo Dam operators contact local downstream communities by phone when needed. Urban areas in Maryland have experienced a frequent history of rapid flash flooding, identifying the need for special warning programs at the county and community level.

Recommendations for Maryland

1. Establish an emergency radio system between Conowingo Dam and downstream emergency action agencies.

2. Establish the most appropriate and direct method of transferring NWS river forecasts to Maryland communities.

3. Implement a flash flood warning program in Maryland.

Findings -- County Government

County government is the level of government with the greatest potential of assemblying and managing the resources necessary to coordinate and direct community flood warning actions. Therefore, the qualities and capabilities of county emergency preparedness staff, working in support of elected officials, is the key to planned local flood warning actions. Full time trained leadership at the county level is needed to carry out the organization, coordination and decision-making to most effectively use county and community staff, equipment and volunteer resources. To be effective, county staff need to have a clear designation of authority and responsibility, with established decision-making delegated by elected officials. Staff needs sufficient training to perform this function.

Recommendations to Counties

1. Assign emergency preparedness authority and responsibility to a full time staff person and insure competency through participation in training and test exercises. Give staff responsibility for coordination, training and operational management during flood emergencies.

2. Organize an emergency operating center and, wherever possible, a communications center capable of coordinating all emergency actions. Insure emergency communications capabilities from county centers to all flood prone communities.

3. County emergency preparedness agencies must assume a strong leadership role to develop and operate an improved local flood forecasting and warning system. This can best be developed through the use of two technical groups: (1) emergency planning and (2) emergency operations staffed on a part-time basis from agencies and industry in the county. Coordinators from each group should serve as a technical advisor to the county civil defense director.

Findings -- Local Government

Action by local government officials, employees and volunteers is the focal point of flood damage reduction. Training and coordination of community resources and actions are needed for an effective program. During a flood, pre-planned and tested action is needed. Many communities do not have disaster preparedness plans.

Recommendations to Communities

1. Develop a flood evacuation plan. Identify flood prone areas, evacuation routes and command centers out of floodable areas. Fit needs to resources and establish operational procedures through a comprehensive plan. Coordinate and pre-test to insure maximum damage reduction and protection of lives.

2. Flood prone communities request evacuation planning assistance programs available from the Corps of Engineers.

Need for Ongoing System Review

The organization and coordination of the flood forecasting system determines, to a large degree, how effective the system operates. The following findings describe system organizational coordination and makes recommendations for improvement.

Findings

The existing flood forecasting system has evolved over a number of years with equipment and organizational methods an outgrowth of this development. The National Weather Service has the responsibility of coordination of the federal system, with support by USGS and the Corps of Engineers. Coordination with state and local government, however, has not been given the attention that it needs. Federal agencies have held independent separate reviews with the states; however, no overall review has been carried out with all affected state and federal agencies.

Federal agencies, reflecting their different concerns and objectives, have made many recent additions in equipment. The listings of gaging equipment, provided in the appendices, and the review of the operations of the flood forecasting system, provided in earlier chapters, reflect the changing complexity of the system and the need for continuing review.

Other changes affect the operation of the system. States have changing requirements for flood fighting operations and communities have special needs for flood warnings.

A scheduled periodic review of system components and operational procedures is needed for most effective coordination and for planning system improvements.

Recommendations

1. The Susquehanna River Basin Commission establish and chair a review board consisting of representatives of appropriate federal and state agencies. Review flood warning system operations at annual or semi-annual board meetings and develop recommendations for further improvements to the system. Recommendations developed to be discussed in public session at a regular meeting of the Commission and notice forwarded to approrpiate elected of-

ficials and agency heads. Coordination of follow-up actions by the Susquehanna River Basin Commission, as necessary.

2. Special needs of self-help programs for local communities be evaluated and improvements implemented, as needed.

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APPENDIX A

RAIN GAGES USED FOR RIVER FORECASTING

SUSQUEHANNA RIVER BASIN

Key to Charts

Table 1) North Branch Sub-basin

Table 2) Chemung Sub-basin

Table 3) Main Stem (Waverly, NY to Danville, PA)

Table 4) West Branch Susquehanna Sub-basin

Table 5) Juniata Sub-basin

Table 6) Main Stem (Sunbury, PA and South)

Table 7) Outside but Adjacent to Basin

KEY TO CHARTS

Name: a) Numbers and letters directly following town name indicate distance (in miles) and direction from town the gage is located.

Equipment: FP - Fischer and Porter Weighing and Recording Gage

Universal - Universal Weighing and Recording Gage

8 inch - Standard 8 inch gage

DARDC - Device for Automatic Remote Data Collection

T. Bucket - Tipping Bucket Gage

Reporting Method: A - Reports received at 6-hour intervals at Weather Service FAA stations.

B - Reports received at 7:00 a.m. daily.

C - Reports when rain exceeds ½" within 24 hours; then reports every 6 hours until rain ends.

D - As in "C", except when any rain occurs.

E - Report received via computer from Baltimore District Office, Corps of Engineers (Radio back-up).

F - Report received as requested during flood.

G - Telemeter can be interrogated at any time DARDC's every 6 hours by ADAS.

1 - Radio and/or telephone report from dam operator daily at 7:00 a.m.

2 - Teletype report from Harrisburg RFC.

3 - Report via terminal from Albany WSFO.

4 - Report via terminal from Buffalo WSFO.

5 - When over 1" rainfall is included in teletype report from MARFC at Harrisburg.

Observer: Lists organizations or NWS cooperative observers (private) responsible for gage readings.

Abbreviations:

AP - Airport

ADAS - Automatic Data Acquisition System

COE - Corps of Engineers

DER - Pennsylvania Department of Environmental Resources

FAA - Federal Aviation Administration

NWS - National Weather Service

NWS-2 - National Weather Service second order station

WSO - Weather Service Office

WSFO - Weather Service Forecast Office

TABLE 1 - RAIN GAGES USED FOR RIVER FORECASTING: NORTH BRANCH BASIN - OCTOBER 1976
(Page 1 of 2)

NAME	LOCATION LATITUDE	LONGITUDE	EQUIPMENT	REPORTING METHOD NWS	COE	OBSERVER
Arnot Lodge, NY	42° 16'	76° 38'	FP, DARDC	B,G	3	---
Bainbridge, NY	42° 18'	75° 29'	8 inch	B	2,3	Private
Binghamton,WSO, NY	42° 13'	75° 59'	Universal	A,B	B,2,3	NWS
Chepachet, NY	42° 54'	75° 07'	8 inch	C	3	Private
Cincinnatus, NY	42° 32'	75° 34'	8 inch	C	3	Private
Cooperstown, NY	42° 42'	74° 55'	8 inch	C	3	Private
Cortland, NY	42° 36'	76° 11'	8 inch	C	3	Private
Davenport, NY	42° 28'	74° 51'	FP, DARDC	B,G	3	---
East Sidney Lake,NY	42° 20'	75° 14'	Universal	B,E	1,F	COE
Hunts Corners, NY	42° 26'	76° 07'	FP, DARDC	B,G	3	---
Lincklaen, NY	42° 42'	75° 53'	8 inch	C	3	Private
Lisle, NY	42° 21'	76° 00'	8 inch	C	3	Private
Montrose, PA	41° 50'	75° 52'	FP, DARDC	B,G	5	Private
Morrisville, NY	42° 54'	75° 39'	FP	C	3	*Inactive
New Berlin, NY	42° 37'	75° 20'	8 inch	C	3	Private
Newark Valley, NY	42° 13'	76° 12'	FP, DARDC	B,G	3	---
North Edmeston, NY	42° 44'	75° 16'	FP, DARDC	B,G	3	---
Norwich, NY	42° 32'	75° 31'	8 inch	C	3	Private

* - Scheduled for DARDC installation.

TABLE 1 - RAIN GAGES USED FOR RIVER FORECASTING: NORTH BRANCH BASIN - OCTOBER 1976
(Page 2 of 2)

NAME	LOCATION LATITUDE	 LONGITUDE	EQUIPMENT	REPORTING METHOD NWS	 COE	OBSERVER
Oneonta, NY	42° 31'	75° 04'	Universal	A	3	NWS-2
Rockdale, NY	42° 23'	75° 24'	8 inch	C	3	Private
Sherburne 2S, NY	42° 39'	75° 29'	8 inch	C	3	Private
Spencer 3W, NY	42° 12'	76° 34'	8 inch	C	3	Private
Truxton, NY	42° 43'	76° 01'	8 inch	C	3	Private
Unadilla, NY	42° 19'	75° 19'	8 inch	C	3	Private
Whitney Pt. 5E, NY	42° 20'	75° 52'	8 inch	C	3	Private
Whitney Pt.Lake,NY	42° 21'	75° 58'	FP, 8 inch	B,E	1,F	COE
Windsor, NY	42° 05'	72° 38'	FP, DARDC	B,G	3	Private (Inactive)

TABLE 2 - RAIN GAGES USED FOR RIVER FORECASTING: CHEMUNG BASIN - OCTOBER 1976
(Page 1 of 2)

NAME	LOCATION		EQUIPMENT	REPORTING METHOD		OBSERVER
	LATITUDE	LONGITUDE		NWS	COE	
Addison, NY	42° 06'	77° 14'	8 inch	C	4	Private
Alfred, NY	42° 15'	77° 48'	8 inch	C	4*	Private
Almond Lake, NY	42° 21'	77° 42'	Universal	B,E	1,F	COE
Austinburg 2W, PA	42° 00'	77° 32'	8 inch	C	4	Private
Bath, NY	42° 20'	77° 20'	8 inch	C	4	Private
Bradford 1NW, NY	42° 23'	77° 07'	8 inch	C	4	Private
Chemung, NY	42° 00'	76° 38'	8 inch	B	2,4	Private
Corning 2SE, NY	42° 07'	77° 04'	8 inch	C	2,4	Private
Covington 2WSW, PA	41° 44'	77° 07'	8 inch	B	2	Private
Elmira, NY	42° 06'	76° 49'	8 inch	C	4	Private
Haskinville, NY	42° 25'	77° 34'	8 inch	C	4	Private
Hornby, NY	42° 14'	77° 03'	FP, DARDC	B,G	4	---
Jackson Summit, PA	41° 57'	77° 01'	FP, DARDC	B,C,G	2	Private
Lindley, NY	42° 02'	77° 08'	8 inch	C	2,4	Private
Middlebury Center, PA	41° 55'	77° 19'	FP, DARDC	B,G	2	---
Morris Run, PA	41° 40'	77° 02'	FP, DARDC	B,G	2	---
Prattsburg 2NW, NY	42° 32'	77° 18'	8 inch	C	4	Private

* - .25 of rain calls COE.

TABLE 2 - RAIN GAGES USED FOR RIVER FORECASTING: CHEMUNG BASIN - OCTOBER 1976
(Page 2 of 2)

NAME	LOCATION		EQUIPMENT	REPORTING METHOD		OBSERVER
	LATITUDE	LONGITUDE		NWS	COE	
Sabinsville 3SE,PA	41° 50'	77° 28'	8 inch	C	2	Private
Tioga Hammond Dam, PA	41° 54'	77° 09'	FP, 8 inch	B,E	1,F	COE
West Cameron, NY	42° 13'	77° 25'	8 inch	C	2,4	Private
West Jasper, NY	42° 09'	77° 34'	FP, DARDC	B,G	4	---
Cowanesque Lake, PA			?	B,E	1,F	COE

TABLE 3 - RAIN GAGES USED FOR RIVER FORECASTING: MAIN STEM: WAVERLY TO DANVILLE
(Page 1 of 1)

OCTOBER 1976

NAME	LOCATION		EQUIPMENT	REPORTING METHOD		OBSERVER
	LATITUDE	LONGITUDE		NWS	COE	
Canton Inn, PA	41° 40'	76° 52'	8 inch	B	5	Private
Danville, PA	40° 58'	76° 37'	8 inch	B	2	Private
Noxen, PA	41° 25'	76° 03'	FP, DARDC	B,G	5	---
Rushville, PA	41° 47'	76° 07'	8 inch	C	5	Private
Shickshinny 3N, PA	41° 12'	76° 08'	Universal	C	5	Private
Stillwater Dam, PA	41° 41'	75° 29'	FP, 8 inch	B,E	1,F	COE
Towanda, PA	41° 45'	76° 25'	8 inch	B	2	Private
Troy, PA	41° 47'	76° 47'	8 inch	C	5	Private
Wilkes-Barre, PA	41° 17'	75° 51'	8 inch	B	2	Private
Wilkes-Barre, Scranton, WSO, PA	41° 20'	75° 44'	Universal	A	2	NWS

TABLE 4 - RAIN GAGES USED FOR RIVER FORECASTING: WEST BRANCH SUSQUEHANNA RIVER
(Page 1 of 3)
OCTOBER 1976

NAME	LOCATION		EQUIPMENT	REPORTING METHOD		OBSERVER
	LATITUDE	LONGITUDE		NWS	COE	
Alvin R. Bush Dam, PA	41° 22'	77° 56'	FP, 8 inch	B,E	1,F	COE
Austin, PA	41° 38'	78° 05'	8 inch	C	5	Private
Barbours, PA	41° 24'	76° 48'	8 inch	F	5	Private
Bodines, PA	41° 27'	76° 59'	8 inch	F	5	*
Carrolltown, PA	40° 35'	78° 42'	8 inch	B	5	Private
Cedar Run, PA	41° 31'	77° 27'	8 inch	B	5	Private
Cherry Springs, PA	41° 40'	77° 49'	FP, DARDC	B,G	5	---
Clarence, PA	40° 03'	77° 56'	8 inch	B	5	Private
Clearfield, PA	41° 01'	78° 27'	8 inch	C	2	Private
Cresson 1SE, PA	40° 27'	78° 34'	8 inch	B	5	Cresson St. School Hospital
Curwensville Lake, PA	40° 57'	78° 32'	Universal 8 inch	B,E	1,F	COE
Dushore 2SSW, PA	41° 29'	76° 25'	FP, 8 inch	B,G	5	Private
Eaglesmere, PA	41° 24'	76° 35'	FP, DARDC, 8 inch	B,G	5	Private
Emporium, PA	41° 30'	78° 14'	8 inch	B	5	Private
English Center, PA	41° 26'	77° 17'	FP, DARDC, 8 inch	B	5	Private
Germania, PA	41° 39'	77° 40'	FP, 8 inch	B	5	Private
Jersey Shore, PA	41° 12'	77° 15'	8 inch	C	5	Private

* - Possible scheduled for DARDC.

TABLE 4 - RAIN GAGES USED FOR RIVER FORECASTING: WEST BRANCH SUSQUEHANNA RIVER
(Page 2 of 3) OCTOBER 1976

NAME	LOCATION LATITUDE	LOCATION LONGITUDE	EQUIPMENT	REPORTING METHOD NWS	REPORTING METHOD COE	OBSERVER
Lock Haven, PA	41° 07'	77° 27'	8 inch	C	2	Sewage Treatment Plant
Madera, PA	40° 50'	78° 26'	Universal	C	5	Private
Millville 2SW, PA	41° 06'	76° 34'	FP, DARDC, 8 inch	B,G	5	Private
Milton, PA	41° 01'	76° 51'	8 inch	C	5	Private
Philipsburg AP, PA	40° 54'	78° 05'	Universal, 8 inch	A	5	FAA
Piper, PA	41° 11'	78° 09'	FP, DARDC	B,G	2	---
Prince Gallitzin, PA	40° 39'	78° 33'	8 inch	F	5	DER
RB Winter State Park, PA	40° 59'	77° 11'	8 inch	F	5	DER
Renovo 5S, PA	41° 14'	77° 46'	FP, DARDC	B,G	2	DER
Sayers Dam, PA	41° 03'	77° 38'	Universal, 8 inch	B,E	1,F	COE
Shunk, PA	41° 33'	76° 45'	8 inch	F	5	Private
Sinnemahoning, PA	41° 19'	78° 05'	8 inch	B	2	Private
Sizerville, PA	41° 36'	78° 10'	FP, DARDC	B,G	5	---
Slate Run Tower,PA	41° 28'	77° 34'	FP, DARDC	B,G	5	DER
State College, PA	40° 48'	77° 52'	Universal, 8 inch	B	5	Pa. St. University
Stevenson Dam, PA	41° 24'	78° 01'	Universal, 8 inch	B	1,F	DER

TABLE 4 - RAIN GAGES USED FOR RIVER FORECASTING: WEST BRANCH SUSQUEHANNA RIVER
(Page 3 of 3)

OCTOBER 1976

NAME	LOCATION		EQUIPMENT	REPORTING METHOD		OBSERVER
	LATITUDE	LONGITUDE		NWS	COE	
Unityville, PA	41° 18'	76° 33'	FP, DARDC	B,G	--	---
Weedville 1N, PA	41° 18'	78° 29'	Universal, 8 inch	B	5	Private
Wellsboro 3S, PA	41° 42'	77° 16'	FP, DARDC, 8 inch	B,G	5	Private
Williamsport WSO, PA	41° 15'	76° 55'	Universal, 8 inch	A	B,2	NWS

TABLE 5 - RAIN GAGES USED FOR RIVER FORECASTING: JUNIATA BASIN - OCTOBER 1976
(Page 1 of 1)

NAME	LOCATION		EQUIPMENT	REPORTING METHOD		OBSERVER
	LATITUDE	LONGITUDE		NWS	COE	
Blue Knob, PA	40°20'	78°34'	FP, DARDC	B,G	5	----
Buffalo Mills, PA	39°57'	78°39'	8 inch	B	5	Private
Huntingdon, PA	40°30'	78°01'	8 inch	B	2	Private
Lewistown, PA	40°36'	77°35'	8 inch	B	2	FMC Corp.
Mapleton Depot, PA	40°24'	77°56'	8 inch	B	2	Private
Martinsburg, AP (Altoona), PA	40°18'	78°19'	Universal, 8 inch	A	5	FAA
Milroy, PA	40°44'	77°38'	FP, DARDC	B,G	5	----
Mount Union, PA	40°24'	77°53'	FP, DARDC	B,G	5	Mount Union
Newport, PA	40°29'	77°08'	8 inch	B	2	Private
Perulack, PA	40°22'	77°39'	FP, DARDC	B,G	5	----
Raystown Lake, PA	40°26'	78°00'	Universal, 8 inch	B,E	1,F	COE
Saxton, PA	40°12'	78°15'	8 inch	B	2	Private
Shade Gap, PA	40°11'	77°52'	FP, DARDC	B,G	5	Private
Stonerstown near Saxton, PA	40°13'	78°15'	FP, DARDC	B,G	5	----
Tyrone, PA	40°40'	78°14'	FP, DARDC, 8 inch	B,G	5	Bor. of Tyrone
Williamsburg, PA	40°27'	78°12'	8 inch	B	2	Private
Wolfsburg, PA	40°03'	78°35'	8 inch	B	5	Private

TABLE 6 - RAIN GAGES USED FOR RIVER FORECASTING: MAINSTEM - SUNBURY AND SOUTH

(Page 1 of 2)

OCTOBER 1976

NAME	LOCATION		EQUIPMENT	REPORTING METHOD		OBSERVER
	LATITUDE	LONGITUDE		NWS	COE	
Bloserville 1N, PA	40°16'	77°22'	FP, DARDC	B,G	5	Private
Conowingo Dam, MD	39°39'	76°10'	Universal, 8 inch	B*	----	Phila. Electric
Craighead, PA	40°09'	77°10'	8 inch	C	5	Private
Fort Indiantown Gap, PA	40°26'	76°34'	8 inch	F	----	
Gardners, PA	40°01'	77°12'	8 inch	B	5	Private
Harrisburg AP, PA	40°13'	76°51'	T. bucket, 8 inch	A,B	2	FAA
Hershey, PA	40°17'	76°39'	8 inch	C	----	
Holtwood, PA	39°50'	76°20'	Universal, 8 inch	B*	----	PP&L
Huntsdale, PA	40°06'	77°18'	FP, 8 inch	C	5	Private
Inglenook, PA	40°26'	76°57'	8 inch	F	5	Private
Joliett, PA	40°37'	76°28'	FP, DARDC	B,G	5	DER
Klingerstown, PA	40°41'	76°39'	Universal, FP, 8 inch	F	5	
Lancaster 2NE, PA	40°03'	76°17'	Universal, 8 inch	B*	----	Lancaster Water Bureau
Lebanon 2W, PA	40°20'	76°28'	FP, DARDC	B,G	5	Lebanon Sewage Treatment Plant
Loysville, PA (5)	40°22'	77°21'	8 inch	B	5	Youth Development Center

* - Safe Harbor calls each station then NWS calls Safe Harbor.

TABLE 6 - RAIN GAGES USED FOR RIVER FORECASTING: MAINSTEM - SUNBURY AND SOUTH
(Page 2 of 2)

OCTOBER 1976

NAME	LOCATION		EQUIPMENT	REPORTING METHOD		OBSERVER
	LATITUDE	LONGITUDE		NWS	COE	
Mahonoy City 2W, PA (3)	40°50'	76°08'	8 inch	C	5	Private
Millersburg 2E, PA	40°32'	76°55'	FP, DARDC	B,G	5	Private
Millheim, PA (4)	40°53'	77°29'	Universal, 8 inch	C	5	Private
Pine Grove, PA	40°32'	76°24'	8 inch	C	5	Private
Pine Grove Furnace, PA	40°01'	77°18'	8 inch	C (1.00)	5	DER
Ranshaw, PA (3)	40°47'	76°31'	FP, DARDC	B,G	5	----
Safe Harbor, PA	39°55'	76°23'	FP, 8 inch	B*	----	S. H. Water and Power Co.
Selinsgrove, PA	40°48'	76°52'	FP, 8 inch	B	2	Private
Shiremanstown, PA	40°15'	77°00'	8 inch	B	----	Private
York Haven, PA	40°07'	76°43'	Universal, 8 inch	B*	----	Met. Ed. Co.
York Indian Rock Dam, PA	39°55'	76°45'	Universal, 8 inch	B,E		COE

* - Safe Harbor calls each station then NWS calls Safe Harbor.

TABLE 7 - RAIN GAGES USED FOR RIVER FORECASTING: OUTSIDE OF BASIN - OCTOBER 1976
(Page 1 of 3)

NAME	LOCATION		EQUIPMENT	REPORTING METHOD		OBSERVER
	LATITUDE	LONGITUDE		NWS	COE	
	STATIONS USEFUL TO THE EASTERN BASIN					
Cobleskill, NY	42°40'	74°30'	8 inch	C		
Lansing Manor, NY	42°28'	74°27'	Universal	C		
Little Falls Reservoir, NY	43°04'	74°52'	8 inch	C		
Syracuse WSO AP, NY	43°07'	76°07'	Universal, 8 inch	A		NWS
Utica FAA AP, NY	43°09'	75°23'	8 inch	A		FAA
	STATIONS USEFUL TO THE CHEMUNG BASIN					
Angelica, NY	42°18'	78°01'	8 inch	B		
Dansville, NY	42°34'	77°34'	Universal	A		
Raymond, PA	41°52'	77°52'	8 inch	C		
Whitesville, NY	42°02'	77°46'	8 inch	C		
	STATIONS USEFUL TO THE WEST BRANCH BASIN					
Bradford FAA, AP, PA	41°48'	76°38'	Universal, 8 inch	A		FAA

TABLE 7 - RAIN GAGES USED FOR RIVER FORECASTING: OUTSIDE OF BASIN - OCTOBER 1976
(Page 2 of 3)

NAME	LOCATION		EQUIPMENT	REPORTING METHOD		OBSERVER
	LATITUDE	LONGITUDE		NWS	COE	
Caudersport 5NW, PA	41°50'	78°04'	8 inch	C		
Dubois, FAA AP, PA	41°11'	78°54'	Universal, 8 inch	A		FAA
Raymond, PA	41°52'	77°52'	8 inch	C		
Stump Cr. 2SW, PA	41°00'	78°51'	FP, DARDC	B,G		
STATIONS USEFUL TO THE JUNIATA BASIN						
Blairsville, PA	40°27'	79°09'	8 inch	B		Inactive
McConnellsburg, PA	39°56'	78°00'	FP, DARDC, 8 inch	B,G		Private
STATIONS USEFUL TO THE MAINSTEM - SUNBURY AND SOUTH						
McConnellsburg, PA	39°56'	78°00'	FP, DARDC, 8 inch	B,G		Private
*South Mountain, PA	39°51'	77°30'	8 inch	B		Pa. Dept. of Health
Zerby AP, PA	40°42'	76°23'	Universal, 8 inch	C		King Coal Aviation, Inc.
*Plesant Mount, PA	41°44'	75°27'	FP, 8 inch	B		Private
Chambersburg, PA	39°56'	77°38'	FP, 8 inch	C	5	
Fayetteville 9NE, PA	39°59'	77°24'	FP, DARDC	B,G	5	

* - Out of basin, but used in runoff estimating routine.

TABLE 7 - RAIN GAGES USED FOR RIVER FORECASTING: OUTSIDE OF BASIN - OCTOBER 1976
(Page 3 of 3)

NAME	LOCATION		EQUIPMENT	REPORTING METHOD		OBSERVER
	LATITUDE	LONGITUDE		NWS	COE	
Freeland	41°01'	75°54'	8 inch	.10"		
Goldsboro	41°15'	75°27'	8 inch	.10"		

APPENDIX B

RIVER GAGES USED FOR RIVER FORECASTING

SUSQUEHANNA RIVER BASIN

Key to Charts Outside Staff Gage Types

Table 1) North Branch Sub-basin

Table 2) Chemung Sub-basin

Table 3) Main Stem (Towanda, PA to Danville, PA)

Table 4) West Branch Susquehanna Sub-basin

Table 5) Juniata Sub-basin

Table 6) Main Stem (Sunbury, PA and South)

KEY TO CHARTS

USGS Gage Number - Assume gage is stage - flow rated unless indicated otherwise here.

Location - Abbreviations:

RB - Right Bank	DS - Downstream
LB - Left Bank	CH - County Highway
US - Upstream	SH - State Highway

Operation and Maintenance (O and M) Agency, Equipment, (Cooperator):

Dig. Recorder: Digital recording gage

Graph Recorder: Graphic recording gage

BDT: Similar to telemark telemetering gage

The Cooperator provides financial assistance in operating the gage.

USGS - United States Geological Survey

COE - Corps of Engineers

NWS - National Weather Service

DPW - Department of Public Works

FPC - Federal Power Commission

DER - Pennsylvania Department of Environmental Resources

DEC - New York Department of Environmental Conservation

USGS 7-1/2 minute topographical quadrant map: indicates map where precise location of gage can be determined. (NP) indicates gage is not explicitly plotted on the map.

NWS Stage-Damage Information: Yes indicates that a verbal and/or graphical description of damage and flooded areas versus height indicated on gage is available for the local community near the gage.

NWS Receipt of Reports:

A - Telemark or BDT phone reports received at 7:00 a.m., 7:00 p.m. normally. Dialed at 1:00 p.m. when needed DARDCS automatically report every six hours.

B - Telemetered gages can be interrogated when required

C - Observer reports at 7:00 a.m. with 7:00 a.m. river data

D - Observer reports at 7:00 a.m. with 7:00 a.m. and previous 7:00 p.m. river data

E - Observer calls when the river reaches predetermined stage and every 6 hours until the river is reported below that stage.

F - Observer calls if _______ local rain falls and gives rain and river report.

G - Gage reports via Swatara Self-Help Program

Corps of Engineers Receipt of Reports:

A - Reports received via radio or telephone from ______ dam operator as needed.

B - Reports received via radio or telephone from ______ dam operator daily.

C - Reports received for (time) via terminal from ( ).

D - Reports received for (time) via teletype from Harrisburg RFC.

E - Telemark can be interrogated when required.

F - Reports not normally received.

OUTSIDE STAFF GAGE TYPES

/N/ -- NWS - type is generally graduated every tenth of a foot. Numbers are large and can be read from several feet away.

/U/ -- USGS - type is graduated every 0.02 feet. Numbers are fairly small and cannot be read from more than a few feet away.

TABLE 1 - RIVER GAGES USED FOR FLOOD FORECASTING - NORTH BRANCH SUBBASIN TO WAVERLY, NY AS OF OCTOBER 1976

USGS GAGE NUMBER	NAME	LOCATION		O and M AGENCY EQUIPMENT (COOPERATOR)	USGS 7-1/2' TOPO QUAD SHEET	DRAINAGE AREA (mi²)	GAGE ZERO DATUM (ft.above m.s.l.)	NWS FLOOD STAGE (ft. on gage) ELEVATION (ft.)	NWS STAGE-DAMAGE INFO	NWS RECEIPT OF REPORTS		COE RECEIPT OF REPORTS	
		LATITUDE	LONGITUDE							DAILY	FLOOD REPORTS	DAILY	FLOOD REPORTS
01500000	Ouleout Cr. at E. Sidney, NY	42°20'00"	75°14'07" RB 0.2 mi. DS of bridge CH 44, 0.4 mi. DS East Sidney Dam, 4.0 mi. US of mouth.	USGS dig. recorder USGS staff gage/u/ USGS electric tape (COE, DEC)	Franklin, NY (NP)	103	1086.31	-----	----	-----	-----	B:East Sidney	A:East Sidney
01500500	Susquehanna R. at Unadilla, NY	42°19'17"	75°19'01" RB 25 ft. DS of bridge St. bridge, 1.0 mi. US of Carrs Cr., 1.6 mi. DS of Ouleout Cr.	USGS dig. recorder USGS wire weight (DS side of bridge) USGS electric tape (COE, DEC) USGS telemark (COE)	Unadilla, NY	982	996.08	11 1007	Yes	A:7AM only	A,B E	B:East Sidney; C:7 AM, Albany WSFD D:7 AM, 7 PM	A:East Sidney C:7 AM, 1 PM, 7 PM, Albany WSFD D:7 AM, 1 PM, 7 PM E
01502500	Unadilla R. at Rockdale, NY	42°22'40"	75°24'23" RB 400 ft. DS of Chenango-Otsego CH bridge, 0.7 mi. DS of Kent Brook, 300'E of SH 8.	USGS wire weight USGS dig. recorder USGS staff gage/u/ (US of shelter in tree) (COE, DEC) NWS DARDC	Guilford, NY	520	992.11	11 1003	Yes	A C	A,B E	F	C: 7 AM, 1 PM, Albany WSFD D: 7 AM, 1 PM, 7 PM
NWS rating	Susquehanna R. at Bainbridge, NY	42°17'30"	75°28'35" US side SH 206 bridge	NWS wire weight	Sidney, NY (NP)	1618	955.63	13 969	Yes	C	E	C:7AM, Albany WSFO D:7 AM	C:7 AM, 1 PM, 7 PM, Albany WSFD D:7 AM, 1 PM, 7 PM
01503000	Susquehanna R. at Conklin, NY	42°02'07"	75°48'12" LB at abutment of former highway bridge 500 ft. US of bridge on CH 304,0.7 mi. DS Little Snake Cr., 3.5 mi. DS Pa.-NY state line.	USGS dig. recorder USGS graph recorder USGS wire weight (500 ft. DS on CH 304 bridge) USGS electric tape (COE, DEC) NWS BDT	Binghamton East, NY	2232	840.95	11 852	Yes	A	A,B	C:7 AM, previous 7 PM, Albany WSFD D:7 AM, 7 PM	C:7 AM, 1 PM, 7 PM, Albany WSFO D:7 AM, 1 PM, 7 PM E
01505000	Chenango R. at Sherburne NY	42°40'43"	75°30'39" RB 20 ft. DS of bridge SH 80, 0.5 mi. W of Sherburne, 0.5 mi. DS of Handsome Brook.	USGS dig. recorder USGS electric tape (COE, DEC) NWS wire weight (US side of bridge)	Earlville, NY	263	1037.16	8 1045	Yes	F:any	E	F	D:varies
01507000	Chenango R. at Greene, NY	42°19'28"	75°46'18" 0.3 mi. DS SH 206 bridge on LB, 0.6 mi. DS of Birdsall Brook.	USGS graph recorder USGS electric tape (COE, DEC) NWS telemark	Greene, NY	593	892.58	13 906	Yes	A:7 AM only	A,B	B:Whitney Point C:7 AM, previous 7 PM, Albany WSFO	A:Whitney Point C:7 AM, 1 PM, 7 PM, Albany WSFD D:7 AM, 1 PM, 7 PM, E
0151000	Otselic R. at Cincinnatus, NY	42°32'28"	75°53'58" RB 150 ft. US of Mead Brook and 300 ft. DS of CH 159 bridge.	USGS wire weight USGS dig. recorder USGS electric tape (COE, DEC) COE telemark	Cincinnatus, NY	593	1031.67	13 1045	Yes	A:7 AM only	A,B	B:Whitney Point C:7 AM, previour 7 PM, Albany WSFD	A:Whitney Point C:7 AM, 1 PM, 7 PM, Albany WSFD D:7 AM, 1 PM, 7 PM E
Not rated	Tioughnioga R. at Lisle, NY	42°21'00"	76°00'00" US side SH 79 bridge	NWS wire weight NWS staff gage/N/	Whitney Point, NY (NP)	453	956.54	12 969	Yes	F:1/2 in.	E	F	D:varies
Not rated	Tioughnioga R. at Whitney Point, NY	42°19'40"	75°57'50" DS side SH 79 bridge short distance below Otselic R.	NWS wire weight	Whitney Point, NY (NP)	714	934.49	12 946	Yes	F:1/2 in.	E	B:Whitney Point	A:Whitney Point
01511500	Tioughnioga R. at Itaska, NY	42°17'55"	75°54'30" RB 3.8 mi. DS Otselic R.6.0 mi. US from mouth, just DS of bridge.	USGS graph recorder USGS wire weight USGS hook gage (COE, DEC)	Whitney Point, NY	735	917.97	--	---	---	---	F	A:Whitney Point
01512500	Chenango R. nr. Chenango Forks, NY	42°13'05"	75°50'55" LB in Chenango Valley State Park, 1.2 mi. DS of Tioughnioga R. and Chenango Forks	USGS dig. recorder USGS staff gage/u/ USGS electric tape (COE, DEC) NWS telemark	Chenango Forks NY	1483	871.73	10 882	Yes	A	A,B Binghamton Off.checks in severe cases.	C:7 AM, previous 7 PM, Albany WSFD D:7 AM, previous 7 PM	C:7 AM, 1 PM, 7 PM, Albany WSFD D:7 AM, 1 PM, 7 PM E
Not rated	Susquehanna R. at Binghamton, NY	42°05'30"	75°54'50" US side LB end of Washington St. bridge 500' US of Chenango R.	NWS staff gage/N/	Binghamton West, NY (NP)	2291	821.49	14 835	Yes	---	Occasional	F	D:occasional
15135000	Susquehanna R. at Vestal, NY	42°05'30"	76°03'25" LB 400 ft. DS highway bridge, just below abutment of old bridge, 800' US of Choconut Cr.	USGS graph recorder USGS staff gage/u/ USGS wire weight USGS electric tape (COE) NWS telemark	Endicott, NY	3960	799.19	18 817	Yes	A	A,B	C:7 AM, previous 7 PM, Albany WSFD D:7 AM, previous 7 PM	C:7 AM, 1 PM, 7 PM, Albany WSFD D:7 AM, 1 PM, 7 PM E
01515000	Susquehanna R. nr. Waverly, NY	41°59'05"	76°30'05" LB 0.2 mi. US of Cayuta Cr., 0.4 mi. US of East Lockhart St. bridge at Sayre, Pa., 1.0 mi. DS NY-Pa. State line.	USGS dig. recorder USGS graph recorder USGS electric tape (COE, DEC) NWS DARDC	Sayre, Pa.-NY	4773	743.96	--	---	A	A,B	C:7 AM, Albany WSFD	C:7 AM, 1 PM, 7 PM, Albany WSFD D:7 AM, 1 PM, 7 PM

TABLE 2 - RIVER GAGES USED FOR FLOOD FORECASTING - CHEMUNG BASIN AS OF OCTOBER 1976

USGS GAGE NUMBER	NAME	LOCATION		O and M AGENCY EQUIPMENT (COOPERATOR)	USGS 7-1/2' TOPO QUAD SHEET	DRAINAGE AREA (mi^2)	GAGE ZERO DATUM (ft.above m.s.l.)	NWS FLOOD STAGE (ft. on gage) ELEVATION (ft.)	NWS STAGE-DAMAGE INFO	NWS RECEIPT OF REPORTS		C O E RECEIPT OF REPORTS	
		LATITUDE	LONGITUDE							DAILY	FLOOD REPORTS	DAILY	FLOOD REPORTS
	Tioga River at Mansfield, Pa.	41°47'34"	77°04'44"	USGS dig. recorder USGS staff gage/u/ USGS electric tape USGS telemark (COE)	Mansfield, Pa. (NP)	----	----	---	---	---	---	B:Tioga-Hammond	A:Tioga-Hammond
	Tioga River at Tioga Junction, Pa.	41°57'09"	77°06'56"	(as above)	Jackson Summit, Pa.(NP)	----	----	---	---	---	---	B:Tioga-Hammond	A:Tioga-Hammond
	Cowanesque R. at Lawrenceville	41°59'48"	77°08'25"	(as above)	Tioga, Pa. (NP)	----	----	---	---	---	---	B:Cowanesque	A:Cowanesque NOTE: Station pos., datum of gages and drainage areas will be determined in the near future.
01520500	Tioga River at Lindley, NY	42°01'44" LB just DS of CH 120 bridge, 6.0 mi. US of Canisteo River	77°07'57"	USGS dig. recorder USGS telemark USGS staff /N/ USGS electric tape (COE, DEC)	Addison, NY	771	964.50	14 979	Yes	A F:1/2 in.	A,B,E	B:Tioga-Hammond C:7 AM, Buffalo WSFO	A:Tioga-Hammond C:7 AM, 1 PM, 7 PM, Buffalo WSFO D:7 AM, 1 PM, 7 PM E
01524500	Canisteo R. at Hornell, NY	42°18'50" RB 235 ft. US of Erie R.R. bridge, 0.3 mi. US of Crosby Cr., 1.5 mi. DS of Canacadea Cr.	77°39'05"	USGS dig. recorder USGS graph recorder USGS staff gage/u/ (½' intervals) USGS electric tape (COE, DEC) COE telemark	Hornell, NY	158	1131.10	---	---	---	---	B:Almond Dam	A:Almond Dam E
01525500	Canisteo R. at West Cameron, NY	42°13'20" RB 250 ft. DS of CH 119 bridge, 0.3 mi. SE of West Cameron	77°25'05"	USGS graph recorder USGS staff gage/u/ (10' DS of gagehouse) USGS telemark USGS electric tape (COE)	Cameron, NY	340	1037.71	17 1055	Yes	A	A,B	B:Almond Dam D:7 AM, Buffalo WSFO	A:Almond Dam C:7 AM, 1 PM, 7 PM, Buffalo WSFO D:7 AM, 1 PM, 7 PM E
not rated	Canisteo R. at Addison, NY	42°06'20" US side old route 17 bridge, above Tuscarora Cr.	77°14'05"	NWS wire weight DEC staff gages /N/(3) 1-at wire weight side 1-on Tuscarora Cr. just US of mouth 1-just DS of mouth at Tuscarora Cr.	Addison, NY (NP)	528	965.38	17 982	Yes	F:1/2 in.	E	F	D:7 AM, 1 PM, 7 PM
01526500	Tioga R. nr. Erwins, NY	42°07'15" RB 20 ft. DS Mulholland Rd. bridge, 1.1 mi. DS of Canisteo R.	77°07'45"	USGS dig. recorder USGS wire weight USGS electric tape (COE, DEC) NWS DARDC	Addison, NY	1377	931.24	--	---	A	A,B	C:7 AM, Buffalo WSFO	C:7 AM, 1 PM, 7 PM, Buffalo WSFO D:7 AM, 1 PM, 7 PM
01527000	Cohocton R. at Cohocton, NY	42°30'00" LB 450 ft. DS of US 15, 800 ft. DS of small trib., 1.4 mi. US of Reynolds Cr.	77°30'02"	USGS dig. recorder USGS staff gage/u/ USGS electric tape (COE, DEC)	Wayland, NY (NP)	52.2	1275.49	--	---	---	---	F	D:7 AM, 1 PM, 7 PM
not rated	Cohocton R. at Bath, NY	42°19'55" On RR bridge near VA hospital	77°19'30"	NWS staff gage/N/	Bath, NY (NP)	317	1092.4	11 1103	Yes	F:1/2 in.	E	F	D:7 AM, 1 PM, 7 PM
01529500	Cohocton R. nr. Campbell, NY	42°15'10" LB just DS of bridge on town road at junction with CH 125, 1.9 mi. US of Michigan Cr.	77°13'00"	USGS dig. recorder USGS wire weight USGS electric tape DEC staff gage/N/ NWS telemark	Savona, NY	470	1016.34	--	---	A	A,B	C:7 AM, previous 7 PM, Buffalo WSFO	C:7 AM, 1 PM, 7 PM, Buffalo WSFO D:7 AM, 1 PM, 7 PM E
01529950	Chemung R. at Corning, NY	42°08'50" Wire Weight 64 ft. from LB on DS side of bridge St. bridge. Recording gage at Corning Class Works, RB.	77°03'30"	NWS Wire Weight USGS outside staff /N/ USGS dig. recorder USGS telemark (COE) (staff gage 2200' DS (0=914.0) at Pine St. bridge. Staffs at Painted Post on RR bridge	Corning, NY (NP)	2006	913.34	26 939	Yes	A,F:1/2 in.	A,B,E	C:7 AM, Buffalo WSFO	C:7 AM, 1 PM, 7 PM, Buffalo WSFO D:7 AM, 1 PM, 7 PM E
synthetic rating	Chemung R. at Hickling Station	42°07'20" LB, at Power Plant	77°59'02"	New York State Electric and Gas staff gage	Seeley Cr., NY-Pa. (NP)	----	----	--	---	Only if NWS calls	Only if NWS calls	----	----
not rated	Chemung R. at Elmira, NY	42°05'12" LB Lake St. bridge, wire wt. 50 ft. out on US side	76°48'03"	NWS wire weight Outside staff/N/ DPW staff gage	Elmira, NY-Pa. (NP)	2162	834.99	10 845	Yes	F:1/2 in.	E	F	D:7 AM, 1 PM, 7 PM
01531000	Chemung R. at Chemung, NY	42°00'08" RB 100 ft. US of SH 427 bridge, 10 mi. US of mouth	76°38'06"	USGS dig. recorder USGS wire weight (COE,DEC) (on DS side of bridge) NWS BOT telemark	Wellsburg, NY	2506	788.63	12 791	Yes	A,D	A,B,E	C:7 AM, previous 7 PM, Buffalo WSFO D:7 AM, previous 7 PM	C:7 AM, 1 PM, 7 PM, Buffalo WSFO D:7 AM, 1 PM, 7 PM E

TABLE 3 - RIVER GAGES USED FOR FLOOD FORECASTING - MAIN STEM, TOWANDA TO DANVILLE AS OF OCTOBER 1976

USGS GAGE NUMBER	NAME	LOCATION LATITUDE	LOCATION LONGITUDE	O and M AGENCY EQUIPMENT (COOPERATOR)	USGS 7-1/2' TOPO QUAD SHEET	DRAINAGE AREA (mi^2)	GAGE ZERO DATUM (ft. above m.a.l.)	NWS FLOOD STAGE (ft. on gage) ELEVATION (ft.)	NWS STAGE-DAMAGE INFO	NWS RECEIPT OF REPORTS DAILY	NWS RECEIPT OF REPORTS FLOOD REPORTS	C O E RECEIPT OF REPORTS DAILY	C O E RECEIPT OF REPORTS FLOOD REPORTS
01531500	Susquehanna R. at Towanda, Pa.	41°45'55" RB under Bridge St. Bridge, 1.8 mi. US of Towanda Cr.	76°26'28"	USGS outside staff /N/ USGS dig. recorder USGS wire weight USGS electric tape NWS DARDC (DER)	Towanda, Pa.	7797	694.38	16 710	Yes	A,D	A,B,E	D:7 AM, previous 7 PM	D:7 AM, 1 PM, 7 PM
01534000	Tunkhannock Cr. near Tunkhannock, Pa.	41°33'29" LB 300 ft. US of C.S. 6 bridge at Dixon, 20 ft. DS of abandoned bridge, 4.0 mi. US of mouth	75°53'42"	USGS dig. recorder USGS graph recorder USGS wire weight USGS electric tape (DER) NWS BDT	Tunkhannock, Pa.	383	610.50	9 619.5	Yes	A	A,B	D:7 AM, previous 7 PM	D:7 AM, 1 PM, 7 PM E
01534300	Lackawanna R. near Forest City, Pa.	41°40'47" LB 400 ft. DS of SH 171 bridge, 1.3 mi. DS of Stillwater Dam.	75°28'20"	USGS dig. recorder USGS graph recorder USGS staff gage USGS electric tape (COE)	Forest City, Pa. (NP)	38.8	1551.28	---	---	---	---	B:Stillwater	A:Stillwater
01534500	Lackawanna R. at Archbald, Pa.	41°30'16" RB, 0.5 mi. US of White Oak Run and Gilmartin St. bridge.	75°32'33"	USGS dig. recorder USGS outside staff gage /u/ USGS electric tape (DER, COE) NWS telemark	Carbondale, Pa.	108	889.33	---	---	B	B	B:Stillwater	A:Stillwater E
01536000	Lackawanna R. at Old Forge, Pa.	41°21'33" RB, 150 ft. US of DL&W RR bridge, behind abutment wall, 0.5 mi. US of St. John's Cr.	75°44'41"	USGS wire weight USGS dig. recorder USGS staff gage USGS electric tape USGS resistance gage (DER)	Avoca, Pa. (NP)	332	595.26	11 606	Yes	D	E	D:7 AM, previous 7 PM	D:7 AM, 1 PM, 7 PM
01536500	Susquehanna R. at Wilkes-Barre, Pa.	41°15'03" LB at foot of W. Union St., 800 ft. DS of North St. bridge, 1300' US of Market St. bridge, 1.6 mi. US of Toby Cr.	75°52'52"	USGS dig. recorder USGS graph recorder USGS outside staff gage/N/ USGS electric tape (DER) NWS DARDC	Kingston, Pa. (NP)	9960	512.07	22 534	Yes	A,D	A,B,E	D:7 AM, previous 7 PM	D:7 AM, 1 PM, 7 PM
not rated	Susquehanna R. at Bloomsburg, Pa.	40°59'30" US side of SH 48 > bridge 222 ft. from Rt. abutment	76°26'15"	NWS wire weight NWS staff on bldg. #43, Magee Carpet Co., (Staff on boathouse 300 ft. US of bridge)	Catawissa, Pa. (NP)	10560	451.37	19 470	Yes	----	E	----	----
01540500	Susquehanna R. at Danville, Pa.	40°57'29" RB 200 ft. US of Mill St. bridge, 0.8 mi. DS of Mahoning Cr.	76°37'10"	USGS dig. recorder USGS wire weight (on bridge) USGS electric tape USGS outside staff /N/ (DER)	Danville, Pa.	11220	431.29	20 451	Yes	D	E	D:7 AM, previous 7 PM	D:7 AM, 1 PM, 7 PM (When river is above 12 ft.)

TABLE 4 - RIVER GAGES USED FOR FLOOD FORECASTING - WEST BRANCH SUSQUEHANNA RIVER BASIN AS OF OCTOBER 1976

USGS GAGE NUMBER	NAME	LOCATION		O and M AGENCY EQUIPMENT (COOPERATOR)	USGS 7-1/2' TOPO QUAD SHEET	DRAINAGE AREA (mi^2)	GAGE ZERO DATUM (ft. above m.s.l.)	NWS FLOOD STAGE (ft. on gage) ELEVATION (ft.)	NWS STAGE-DAMAGE INFO	NWS RECEIPT OF REPORTS		C O E RECEIPT OF REPORTS	
		LATITUDE	LONGITUDE							DAILY	FLOOD REPORTS	DAILY	FLOOD REPORTS
01541000	W. Br. Susquehanna R. at Bower, Pa.	40°53'49"	78°40'38" RB on DS side of bridge 4.6 mi. DS of Cheat Cr.	USGS dig. recorder USGS graph recorder USGS wire weight	Mahaffey, Pa.	315	1207.14	---	---	---	---	F	A:Curwensville
01541200	W. Br. Susquehanna R. at Curwensville, Pa.	40°57'41"	78°31'10" LB 30 ft. DS of SH 453 bridge, 0.85 mi. DS of dam, 1.8 mi. US of Anderson Cr.	USGS dig. recorder USGS graph recorder USGS wire weight (DER, COE)	Curwensville, Pa.	367	1124.52	---	---	C	E	B:Curwensville	A:Curwensville
Rated USGS	W. Br. Susquehanna R. at Clearfield, Pa.	41°01'20"	78°26'30" DS side 100 ft. from RB on Market St. bridge	NWS wire weight (DER) USGS outside staff (DER): 0.3 mi. DS on Front St., 60 ft. from rear of County Prison, telephone pole	Clearfield, Pa. (NP)	482	1093.90	10 1104	Yes	F:1/2 in.	E	B:Curwensville D:7 AM (if measurable precip.occurs)	A:Curwensville D:7 AM, 1 PM, 7 PM (when river above 6 ft.)
01542500	W. Br. Susquehanna R. at Karthaus, Pa.	41°06'56"	78°06'43" LB 900 ft. US of SB 879 bridge, 1,000 ft. US of Mosquito Cr., 3.3 mi. DS of Moshannon Cr.	USGS dig. recorder USGS wire weight USGS electric tape (DER, COE) NWS DARDC	Karthaus, Pa.	1,462	830.59	19 849	Yes	A	A,B	D:7 AM, previous 7 PM	D:7 AM, 1 PM, 7 PM
01543500	Sinnemahoning Cr. at Sinnemahoning, Pa.	41°19'02"	78°06'12" LB 0.2 mi. US of Grove Run, 0.7 mi. US of Penn Central R.R. bridge.	USGS outside staff /N/ USGS dig. recorder (DER) NWS DARDC	Sinnemahoning, Pa.	685	769.36	---	---	A	A,B	F	A:Stevenson
Not Rated	Sinnemahoning Cr. at Sinnemahoning, Pa.	41°19'10"	78°05'00" DS side of bridge off SH 120, 0.2 mi. DS of Penn Central R.R. bridge.	USGS wire weight (NWS)	Sinnemahoning, Pa.	693	763.36	15 778	Yes	C	E	D:7 AM	D:7 AM, 1 PM, 7 PM
01544000	First Fork Sinnemahoning Cr. nr. Sinnemahoning, PA	41°24'06"	78°01'28" RB 350 ft. DS of Woodrock Run, 1500 ft. US of Roaring Run, 0.75 mi. DS of Stevenson Dam	USGS dig. recorder USGS outside staff gage /u/ (DER, COE)	First Fork, Pa.	245	878.71	---	---	C	E	B:Stevenson	A:Stevenson
01545000	Kettle Cr. nr. Westport, Pa.	41°19'12"	77°52'27" LB 0.4 mi. US of Short Bend Run, 3.5 mi. US of mouth, 5 mi. DS of Kettle Cr. Lake and Bush Dam.	USGS dig. recorder USGS graph recorder USGS staff gage	Renovo West, Pa.	233	728.24	---	---	---	---	F	A:Bush
01545500	W. Br. Susquehanna R. at Renovo, Pa.	41°19'28"	77°45'03" LB 5 ft. US of 8th St. bridge, 1 mi. US of Paddy Run.	USGS outside staff /N/ USGS dig. recorder USGS electric tape (DER) USGS telemark (COE) NWS DARDC	Renovo West, Pa.	2,975	634.19	16 650	Yes	A	A,B	B:Bush D:7 AM, previous 7 PM	A:Bush D:7 AM, 1 PM, 7 PM E:
01545800 Not rated	W. Br. Susquehanna R. at Lock Haven, Pa.	41°08'20"	77°26'30" DS side of Jay St. bridge, 133 ft. from RB Locally owned staff on bridge.	USGS outside staff /N/ USGS dig. recorder NWS wire weight USGS telemark (DER, COE) local staff gages: DS corner Decker bldg., Main St. nr. Jay; Streamword corner of Dunkle bldg. on Shoreword corner Vesper and Jordan.	Lock Haven, Pa. (NP)	3.337	534.95	21 556	Yes	A	A,B	B:Sayers D:7 AM, previous 7 PM	A:Sayers D:7 AM, 1 PM, 7 PM E
01547500	Bald Eagle Cr. at Blanchard, Pa.	41°03'06"	77°36'17" LB 0.4 mi. DS of Sayers Lake and Dam, 0.7 mi. US of Marsh Cr.	USGS dig. recorder USGS graph recorder USGS staff gage (COE)	Beech Creek, Pa.	339	579.79	---	---	---	---	B:Sayers	A:Sayers
01547950	Beech Cr. at Monument, Pa.	41°06'42"	77°42'09" RB 800 ft. DS of bridge 850 ft. DS of Monument Run, 0.6 mi. US of Twin Run, 8.7 mi. US of mouth	USGS dig. recorder USGS wire weight (COE)	Howard, PA	152	----	---	---	---	---	A:Sayers	A:Sayers Gage to be removed FY 77 and equipment relocated.
01548000	Bald Eagle Cr. at Beech Cr. Station, Pa.	41°03'55"	77°34'03" DS end of center pier of bridge just DS of Beech Cr., 3.0 mi. DS of Sayers Lake.	USGS dig. recorder (DER, COE) NWS telemark	Beech Creek, Pa.	559	571.74	8 (bankfull) 580	Yes	A	A,B	B:Sayers	A:Sayers E
01548500	Pine Cr. at Cedar Run, Pa.	41°31'18"	77°26'52" LB DS side of bridge, 2000 ft. DS of Cedar Run, 1.2 mi. US of Gamble Run.	USGS dig. recorder USGS wire weight USGS staff USGS electric tape (DER)	Cedar Run, Pa.	604	780.36	12 792	Yes	D	E	F	D:7 AM, 1 PM, 7 PM, if creek above 6 ft
01549700	Pine Cr. below Little Pine Cr. nr. Waterville, Pa.	41°16'25"	77°19'28" DS side of suspension bridge, 0.9 mi. DS of Ramsey Run, 4.0 mi. DS of Little Pine Cr., 9.2 mi. US of mouth.	USGS wire weight	Waterville, Pa.	944	570.62	--	---	---	---	F	D:7 AM, 1 PM, 7 PM if creek above 8 ft
Not rated	W. Br. Susquehanna R. at Jersey Shore, Pa.	41°12'10"	77°15'10" 120 ft. from LB on US side of bridge at junction of SH 44 and Old U.S. 220.	NWS wire weight (DER) USGS outside staff /N/ (DER) (near bridge and on bridge)	Jersey Shore, Pa. (NP)	5,240	513.19	26 539	Yes	Thursday 1/4 in.	E	F	D:7 AM, 1 PM, 7 PM, if river above 12 ft.
01551500	W. Br. Susquehanna R. at Williamsport, Pa.	41°14'17"	76°59'56" LB US side of Market St. Bridge, 350 ft. US of Hagerman's Run. Wire weight on bridge.	NWS wire weight (USGS, DER) USGS dig. recorder USGS graph recorder USGS electric tape USGS outside staff /N/ USGS inside staff (DER) NWS DARDC	Montoursville South, Pa.	5,682	494.98	20 515	Yes	A,D	A,B,E	A:7 AM, previous 7 PM	D:7 AM, 1 PM, 7 PM
Not rate	W. Br. Susquehanna R. at Milton, Pa.	41°00'44"	76°51'44" on bridge and LB.	USGS outside staff /N/ (DER) staff marked in ½ ft. intervals.	Milton, Pa. (NP)	---	432.45	19 451	Yes	C	E	F	Reports available thru RFC on request
01553500	W. Br. Susquehanna R. at Lewisburg, Pa.	40°58'05"	76°52'25" LB DS side Market St. bridge, 0.2 mi. DS of Buffalo Cr., 7.4 mi. US of mouth.	USGS outside staff /N/ USGS dig. recorder USGS wire weight USGS electric tape USGS inside staff (DER, COE) NWS DARDC	Lewisburg, PA	6,847	428.20	18 446	Yes	A	A,B	D:7 AM, previous 7 PM	D:7 AM, 1 PM, 7 PM

TABLE 5 - RIVER GAGES USED FOR FLOOD FORECASTING - JUNIATA BASIN AS OF OCTOBER 1976

USGS GAGE NUMBER	NAME	LOCATION LATITUDE | LONGITUDE	O and M AGENCY EQUIPMENT (COOPERATOR)	USGS 7-1/2' TOPO QUAD SHEET	DRAINAGE AREA (mi^2)	GAGE ZERO DATUM (ft.above m.s.l.)	NWS FLOOD STAGE (ft. on gage) ELEVATION (ft.)	NWS STAGE-DAMAGE INFO	NWS RECEIPT OF REPORTS		C O E RECEIPT OF REPORTS	
									DAILY	FLOOD REPORTS	IAILY	FLOOD REPORTS
01556000	Frankstown Br. Juniata R. at Williamaburg, Pa.	40°27'47" 78°12'00" LB 10 ft. DS of bridge, 2.5 mi. US of Clover Cr.	USGS dig. recorder USGS wire weight USGS outaide staff /N/ USGS electric tape (DER)	Williamsburg, Pa.	291	831.7B	12 844	Yes	C	E	D:7 AM	D:7 AM, 1 PM, 7 PM, if river above 9 ft. stage
01559000	Juniata R. at Huntingdon, Pa.	40°29'05" 78°01'09" RB 170 ft. DS of Smithfield bridge, 0.8 mi. US of Standing Stone Creek	USGS dig. recorder USGS wire weight USGS outside staff /N/ USGS electric tape (DER, COE, FPC) USGS telemark (COE) NWS DARDC	Huntingdon, Pa.	816	599.69	12 612	Yes	A,C	A,B,E	B:Raystown	A:Raystown D:7 AM, 1 PM, 7 PM E
01562000	Rayatown Br. Juniata R. at Saxton, Pa.	40°12'57" 7B°15'56" LB 500 ft. DS of SH 913 bridge, 1.5 mi. US of Shoup Run	USGS dig. recorder USGS wire weight USGS inaide staffa USGS electric tape (DER) USGS telemark (COE)	Hopewell, Pa.	756	795.77	17 B13	Yes	A,C:if contacted by RFC	A,B,E	B:Raystown D:7 AM, previous 7 PM	A:Raystown D:7 AM, 1 PM, 7 PM E
01563200	Rayatown Br. Juniata R. below Rayatown Dam nr. Huntingdon, Pa.	40°25'44" 77°59'29" LB 1.0 mi. DS of Raystown Dam, 4.7 mi. US of mouth	USGS dig. recorder USGS graph recorder USGS outside staff gage /u/ (COE)	Mount Union, Pa.	960	597.36	--	---	C	E	B:Raystown	A:Raystown
01563500	Juniata R. at Mapleton Depot, Pa.	40°23'32" 77°56'07" RB .25 mi. DS of Scrub Run, 0.3 mi. DS of SH 655 bridge, wire weight on bridge	USGS dig. recorder USGS graph rec. USGS wire weight USGS telemark USGS outaide staff /N/ USGS inaide staff USGS electric tape (DER) NWS DARDC	Mount Union, Pa.	2030	557.31	20 577	Yes	A,D	A,B,E	B:Raystown D:7 AM, previous 7 PM	A:Raystown D:7 AM, 1 PM, 7 PM E
not rated	Juniata R. at Lewistown, Pa.	40°35'35" 77°34'45" Transmitter in FMC Corp. #2 Pump House RB 800 ft. US of SH 103 bridge. Indicator in gate building, wire weight, ataff on bridge	NWS wire weight (DER) NWS remote indicator (resistance gage) USGS outside staff /N/ (DER)	Lewistown, Pa.	2519	443.95	23 467	Yes	D	E	D:7 AM, previous 7 PM	D:7 AM, 1 PM, 7 PM, if river above 10 ft. stage
01567000	Juniata R. at Newport, Pa.	40°28'43" 77°07'46" RB DS side of bridge 1000 ft. US of Little Buffalo Cr. Wire weight on bridge	NWS dig. recorder USGS dig. recorder USCS graph recorder USGS wire weight USGS electric tape USGS inaide staff USGS outside staff /N/ NWS DARDC	Newport, Pa. (NP)	3354	363.93	22 3B6	Yes	A,D	A,B,E	D:7 AM, previous 7 PM	D:7 AM, 1 PM, 7 PM

TABLE 6 - RIVER GAGES USED FOR FLOOD FORECASTING - MAIN STEM SUNBURY AND SOUTH AS OF OCTOBER 1976

USGS GAGE NUMBER	NAME	LOCATION		O and M AGENCY EQUIPMENT (COOPERATOR)	USGS 7-1/2' TOPO QUAD SHEET	DRAINAGE AREA (mi^2)	GAGE ZERO DATUM (ft.above m.s.l.)	NWS FLOOD STAGE (ft. on gage) ELEVATION (ft.)	NWS STAGE-DAMAGE INFO	NWS RECEIPT OF REPORTS		C O E RECEIPT OF REPORTS	
		LATITUDE	LONGITUDE							DAILY	FLOOD REPORTS	DAILY	FLOOD REPORTS
01554000	Susquehanna R. at Sunbury, Pa.	40°50'04" RB on grounda of PP&L generating plant, 1.0 mi. DS of Shamokin Cr.	76°49'37"	USGS dig. recorder USGS inside ataff USGS outside staff /N/ NWS telemark (DER) NWS DARDC USGS wire weight on bridge 1.7 mi. US	Sunbury, Pa. (N), wire weight station plotted	18,300	40B.61	24 432	Yes	A	A,B	D:7 AM, previous 7 PM	D:7 PM, 1 PM, 7 PM E
01570000	Conodoguinet Cr. nr. Hogeatown, Pa.	40°15'08" LB 1000 ft. US of bridge, 0.4 mi. DS of Hogestown Run	77°01'17"	USGS dig. recorder USGS wire seight (DER) NWS DARDC	Wertzville, Pa. (NP)	470	351.00	--	---	A	A,B	F	From RFC upon request.
01570500	Susquehanna R. at Harrisburg, Pa.	40°15'10" On City Island (RB of 'East channel') just DS of Market St. bridge	76°52'27"	USGS dig. recorder USGS graph recorder USGS wire weight USGS outside staff /N/ NWS telemark (DER, FPC) NWS DARDC	Harrisburg W., Pa. (NP)	24,100	290.01	17 307	Yes	A	A,B	D:7 AM, previous 7 PM	D:7 PM, 1 PM, 7 PM E
01573000	Swatara Cr. nr. Harper Tavern, Pa.	40°24'09" LB 10 ft. DS of SH 934 bridge, 8.5 mi. DS of Little Swatara Cr.	76°34'39"	USGS dig. recorder USGS wire weight USGS telemark (DER)	Indiantown Gap, Pa.	337	356.68	B 364	Yes	A	A,B,G	F	From RFC upon request.
01573560	Swatara Cr. nr. Hershey, Pa.	40°17'54" LB 0.4 mi. DS of Manada Cr., 0.5 mi. US of SH 39	76°40'05"	USGS dig. recorder USGS outside staff /N/ USGS telemark (DER)	Hershey, Pa. (NP)	483	325.94	7 333	Yes	A	A,B,G	F	From RFC upon request.
01575000	S. Br. Codorua Cr. nr. York, Pa.	39°55'14" RB 100 ft. DS of dam at pumping station of York Water Co., 200 ft. US of Penn Central RR bridge, 0.5 mi. US of mouth	76°44'57"	USGS dig. recorder USGS staff gage	York, Pa.	117	373.03	--	---	---	---	F	A:York Indian Rock
01575500	Codorus Cr. nr. York, Pa.	39°56'46" LB 0.5 mi. US of Richland Ave. bridge, 2.0 mi. DS of South Branch Codorus Cr.	76°45'20"	USGS dig. recorder USGS staff gage	West York, Pa.	222	356.39	11.5 724	---	---	---	B:York Indian Rock	A:York Indian Rock
01576500	Conestoga R. at Lancaster, Pa.	40°03'00" LB at Penn Central RR bridge, 50 ft. DS of small trib., 500 ft. DS of diversion dam at city water works	76°16'39"	USGS dig. recorder (DER, FPC) USGS outside staff /N/	Lancaster, Pa.	324	245.63	--	---	---	E	----	-----

APPENDIX C

SATELLITE DATA COLLECTION SYSTEMS

(as of December 1977)

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SATELLITE DATA COLLECTION SYSTEMS

December 1977

Satellite Data Collection Systems may help solve the problem of communication between the gages and the River Forecast Center. A Satellite Data Collection System (DCS) is a telemetry system that uses an earth-orbiting satellite to relay data from a very large number of widely distributed transmitting stations to one or a few receiving stations. The three basic elements of any satellite data collection system are: (1) a field radio, usually called a Data Collection Platform (DCP), (2) a radio transponder (receiver/transmitter) on an earth-orbiting satellite, and (3) an earth-receiving station.

At present, there are four coordinated satellite data collection programs in the basin. These programs and the satellite technology involved are explained below.

U.S. Geological Survey -- Susquehanna River Basin Commission Cooperative Program

A cooperative project between the U.S. Geological Survey and the Susquehanna River Basin Commission (SRBC) to test satellite data relay systems has been underway for several years.

The initial phase was to test the reliability of data transmitted from data collection platforms (DCP's) to the LANDSAT (formerly ERTS) satellite. In the LANDSAT SYSTEM data are transmitted from the DCP to the low altitude polar orbiting satellite, relayed to one of several ground receiver sites and transmitted through NASA computers via teletype to the USGS Water Resources Division district office in Harrisburg. Data is converted onto computer cards, computer processed and magnetic disk stored at Reston, Virginia for later use.

In system operations a brief data transmission, known as a "data burst" is emitted once from the DCP every 180 seconds continuously around the clock regardless of whether the satellite is within range. The antenna emits the "data burst" in a 140 degree cone transmission field above the antenna plane. When the satellite is within radio range of approximately 2,000 Km from both a DCP and a receiving station, then the transmission is instantaneously relayed to the receiving station. DCS experiments have demonstrated successful data transmissions during two, and occasionally three, orbits to the receiving stations in Maryland and California during both the daylight and night transits of the satellite.

The LANDSAT-DCS is a random access system with one radio frequency channel. This means the times of an individual DCP's transmissions are completely independent of other DCP's and, therefore, mutual radio interference from two or more DCP's is expected to occur at a random, but predictable, rate. No data are relayed when there is mutual interference of transmissions. With a network of 1,000 DCP's using the LANDSAT-DCS, there is a 95 percent probability that one transmission per DCP will be successfully relayed every 12 hours. For most locations in North America, the satellite is within a range of a DCP and a receiving station only about 2 to 3 percent of the 24-hour day.

It is significant that technicians can easily install and operate the DCP's with a minimum of training. The random-access LANDSAT-DCS permits the field technician to turn on the DCP after installation, with no requirement for knowing the time of DCP transmit nor the precise time of transmissions of any other DCP's in the network.

The modest power requirements of the DCP permit it to be powered by solar panels or a series of low cost disposable dry cell batteries. Four 6-volt dry cell batteries have been used to power a DCP for periods of as much as 6 months. The average power drain is approximately 50 milliwatts during a data transmission to the satellite.

Four LANDSAT-DCP's were installed in the Susquehanna basin. The four DCP's have performed well; the data is considered reliable; and their operation will continue, although some units have been relocated.

The USGS and SRBC, in an effort to improve flood forecasting in the basin, have expanded the satellite data relay program to include, in FY-76, 15 convertible data collection platforms (CDCP's) capable of communicating with NOAA's Geostationary Operational Environmental Satellite (GOES). (A convertible data collection platform is one that can be programmed to communicate with either the LANDSAT or GOES satellite.)

The GOES CDCP's are to act as a "back-up" data collection system for the River Forecast Center in Harrisburg. One distinct advantage of the GOES system is that it employs the use of a geostationary satellite, thus providing for constant data communications. The operating characteristics of the GOES DCP's are discussed in the next section.

Juniata River Basin -- GOES Research Project

The objectives of this USGS sponsored program are to evaluate the Geostationary Operational Environmental Satellite (GOES) system, determine the reliability of the convertible data collection platform and demonstrate the usefulness of data processing through the system. Platforms have been installed on water level sensors at 9 of 14 recording gaging stations currently being operated in the Juniata basin.

The basic system consists of a water level sensor (ADR) interfaced with a self-timed CDCP which transmits data to the GOES satellite which relays it to a ground receiving station where the data is again relayed to the USGS Computer Center in Reston, Virginia. The Pennsylvania USGS District Office accesses the data in the Reston computer through a computer terminal which is virtually real time (meaning very limited delay). The CDCP timer accuracy is critical because each transmission must occur during an assigned time window of about 1 1/2 minutes. Antenna installation is directional.

The first satellite of the NASA/NOAA Synchronous Meteorological Satellite/Geostationary Operational Environmental Satellite Data Collection System (SMS/GOES-DCS, commonly referred to as GOES system) series was launched in May 1974 as the initial part of a multi-satellite system programmed for operation in the last half of the 1970's. The GOES-DCS is operational and uses 150 radio frequency channels for communication, as opposed to the experimental, random access, single channel employed by LANDSAT-DCS. The GOES-DCS operates in a time-ordered or interrogate mode.

In a time-ordered mode of operation, to which 50 GOES channels are dedicated, a DCP is assigned a frequency channel and time interval for transmission. A precision timer in the DCP is set to initiate a transmission during a predetermined time interval, for example, during a two-minute period once every three hours on a particular channel. If the system is well managed, no other DCP will transmit during that time on that channel and reliable communications can be established. The communications rate of the GOES-DCP is much slower than the LANDSAT-DCP and the nominal transmission period for a self-timed DCP is in the range of 10-20 seconds. The DCP precision timer, which generally is designed to be accurate to 1 part in 10^6, is designed to permit a drift of no more than approximately 30 seconds per year in the time of message initiation. Thus, if self-timed DCP's are assigned two-minute reporting intervals and broadcast in the central point of their time interval, they should continue to operate with no mutual interference for at least one year. The GOES-DCS capacity of 50 self-timed channels, with DCP's reporting every three hours with a two-minute reporting interval, totals 4,500 DCP's per satellite.

In the interrogate mode of operation, to which 100 channels are dedicated, a DCP is interrogated through the satellite from the data receiving station. Under command from the receiving station, the satellite initiates a request for a DCP with the specified identification number (ID) to reply on a pre-programmed channel. Upon recognizing its ID,the DCP transmits its data. Under this mode of operation,the receiving station maintains control of the DCP's,causing them to adhere to the receiving station's schedule. In times of emergency, or if communications have failed for some reason, the receiving station can reschedule interrogation and attempt to initiate communications under a new schedule.

The GOES-DCS can initiate interrogation commands at a rate of two interrogations per second per satellite. At that rate,21,600 interrogations can be initiated in a three-hour period. That would permit up to 216 replies per channel per three-hour period, if each reply averaged 50 seconds per transmission. Although the actual system for managing 150 channels of the GOES-DCS is presently evolving, it is obvious that the system is capable of handling a large number of DCP's.

The GOES platforms currently being operated are self-timed and are not subject to interrogation. The platform must be equipped with a receiver to get an interrogate request from the satellite.

Nine sites have had platforms installed and are now operational.

The GOES research project in the Juniata River basin is due to end in September, 1978. It is not known what will happen to the satellite platforms there at that time.

COMSAT Data Relay Project

The beginning of the COMSAT proposal dates back to September, 1975, when COMSAT General Corporation presented the USGS with an unsolicited proposal to conduct a six-month satellite data collection service joint evaluation program. The USGS accepted the proposal and Pennsylvania was selected as one of the platform-installation and test areas. The COMSAT program is basically a test program designed to learn how efficiently a commercially-owned and operated satellite data collection system could be run. The program is intended to closely resemble one which could be obtained by both governmental and private users alike. The COMSAT system uses a geostationary satellite similar to the one used in the NASA/NOAA GOES system. Five COMSAT platforms were installed at gaging stations in the lower Susquehanna basin in October, 1977, and they will remain there for about six months. During that period, data will be collected concurrently by the COMSAT system and by the normal USGS method. At the end of six months, operations will be evaluated and a joint final report will be written. All hardware installed between the USGS hydrologic sensors and the Reston computer will be owned, operated and maintained by COMSAT. The USGS will be responsible for providing hydrologic sensors and associated technical information and assistance in installation of sensor to platform interface, data surveillance and subsequent assistance in the correction of remote equipment malfunctions and normally collected data which will be used for comparison and analyses which will be used in a joint final report.

For the project, COMSAT General Corporation will use an existing Telesat of Canada ANIK geostationary communication satellite. The commercial-type demonstration system will use a small portion of one transponder on a commercial communication satellite, which normally has 12 communications transponders, each of which could carry data from several hundred thousand DCP's. The other transponders will continue to carry high volume commercial telecommunication traffic from and to major population centers. The demonstraton is intended to show that the use of existing commercial satellites, operating at the 4,000 and 6,000 megahertz bands, is technically viable and that it is possible to share the use of the satellite on a noninterference basis with other commercial users. The economic viability of any satellite system depends heavily upon maximizing multiple usage of the expensive space segment to minimize unit utilization cost of the satellite for all users.

The characteristics of the commercial-type DCS system includes some of the best characteristics of the LANDSAT and GOES systems. All of the DCP's in the commercial-type system will be operated in the random-access, self-timed mode, analogous to the LANDSAT system; however, use is made of a geostationary satellite, which means mutual visibility for a large geographic area is maintained. The DCP's are programmed to transmit as frequently as every 15 minutes, although some will operate at transmit intervals of 30 to 60 minutes. The DCP's will transmit at a frequency between 5,925 and 6,425 megahertz and the duration of message transmission will be about 150 milliseconds. Each DCP message will transmit up to 64 bits of sensor data; although, the expansion to a larger data message is possible. In the demonstration, which will include the field testing of only about 15 DCP's, in the States of Virginia, Oregon and Pennsylvania, the probability of mutual interference is small and each DCP will transmit its message once at its assigned time. In an operational system, each message would be transmitted two or more times to decrease the probability of unsuccessful relay of the data because of mutual interference.

At this time, five sites in Pennsylvania are as follows:

Code No.	Location
01554000	Susquehanna River at Sunbury, PA
01570000	Conodoguinet Creek at Hogestown, PA
01567500	Bixler Run at Loysville, PA
01568500	Clark Creek at Carsonville, PA
0157550	Codorus Creek near York, PA

Corps of Engineers GOES Program

In FY-77, installation of 16 GOES-DCP's was essentially completed with the COE providing the funding and USGS making the installation. The platforms have been installed to aid the COE in reservoir regulations.

Summary

The USGS/SRBC and USGS/COE FY-77 programs have resulted in at least 39 permanent installations of satellite platforms in the basin. If the nine Juniata sites remain active, a good basic network will be in place. It is unknown what will become of the COMSAT sites at the end of that test.

At this time, December, 1977, 43 river gage sites in the Susquehanna River Basin have had satellite data collection platforms and one is being moved. If the COMSAT sites are continued and installations are completed according to schedule, there will be 50 DCP's at 47 sites. At three locations six DCP's will be used to evaluate the different data collection systems. When all DCP's are installed, there will be 35 river gage installations with both satellite and phone interrogation, 7 installations with satellite only telemetry and 5 with phone only telemetry. This will increase the number of river gage sites with either telephone or satellite data telemetry to 47 locations, with five river gages with only phone interrogation. (There are six satellite stations in the basin which are not included in the river forecast system.) Completion of the satellite data collection system provides an alternate means of obtaining river gage levels without major dependence on the telephone system that is subject to outages in a major flood event.

Currently, MARFC is obtaining hourly gage readings from GOES DCP's by polling the NWS computer at Suitland, Maryland. The most recent data, obtained in this manner, varies from minutes to three hours old. This system is valuable also in that the hourly readings provide an opportunity to detect gage malfunctions quickly.

Table 1, on page C-8, lists Satellite Data Relay Project Stations and Figure 1, on page C-10, shows platform locations.

TABLE 1

SATELLITE DATA RELAY PROJECT STATIONS

GOES - Juniata FY 1976-77

1.	01556000	Frankstown Br., Juniata River at Williamsburg, PA
2.	01558000	Little Juniata River at Spruce Creek, PA
3.	01559000	Juniata River at Huntingdon, PA
4.	01560000	Dunning Creek at Belden, PA
5.	01562000	Raystown Br. Juniata River at Saxton, PA
6.	01563200	Raystown Br. Juniata River below Raystown Dam nr. Huntingdon, PA
7.	01563500	Juniata River at Mapleton Depot, PA
8.	01564500	Aughwick Crk. nr. Three Springs, PA
9.	01567000	Juniata River at Newport, PA

GOES - SRBC FY 1976-

1.	01503000	Susquehanna River at Conklin, NY
2.	01509000	Tioughnioga River at Cortland, NY
3.	01515000	Susquehanna River near Waverly, NY
4.	01526500	Tioga River near Erwins, NY
5.	01529950	Chemung River at Corning, NY
6.	01531000	Chemung River at Chemung, NY
7.	10536500	Susquehanna River at Wilkes-Barre, PA
8.	01539000	Fishing Creek nr. Bloomsburg, PA
9.	10540500	Susquehanna River at Danville, PA
10.	01542500	W. Br. Susquehanna River at Karthaus, PA
11.	01543500	Sinnemahoning Creek near Sinnemahoning, PA
12.	01545800	W. Br. Susquehanna River at Lock Haven, PA
13.	01551500	W. Br. Susquehanna River at Williamsport, PA
14.	01554000	Susquehanna River at Sunbury, PA
15.	01570500	Susquehanna River at Harrisburg, PA

LANDSAT USGS-SRBC FY 1976-

1.	0153340	Susquehanna River at Meshoppen, PA
2.	01534000	Tunkhannock Crk. nr. Tunkhannock, PA
3.	01570500	Susquehanna River at Harrisburg, PA
4.	01553500	W. Br. Susquehanna River at Lewisburg, PA (being moved to Susquehanna River at Marietta, PA)

GOES - COE FY 1977-

1.	01500500	Susquehanna River at Unadilla, NY
2.	01502500	Unadilla River at Rockdale, NY
3.	01507000	Chenango River at Green, NY
4.	01510000	Otselic River at Cincinnatus, NY
5.	01512500	Chenango River nr. Chenango Forks, NY
6.	01513500	Susquehanna River at Vestal, NY
7.		Tioga River nr. Mansfield, PA
8.		Tioga River at Tioga Junction, PA
9.	01524500	Canisteo River below Canacadea Crk. at Hornell, NY
10.	01525500	Canisteo River at West Cameron, NY
11.	01529500	Cohocton River near Campbell, NY
12.	01531500	Susquehanna River at Towanda, PA
13.	01536000	Lackawanna River at Old Forge, PA
14.	01545500	W. Br. Susquehanna River at Renovo, PA
15.	01553500	W. Br. Susquehanna River at Lewisburg, PA
16.	01533400	Susquehanna River at Meshoppen, PA
17.	01541303	(W. Br. Susquehanna River at Hyde, PA. Scheduled new gaging station to be constructed.)

COMSAT FY 1976-77

1.	01554000	Susquehanna River at Sunbury, PA
2.	01567500	Bixler Run near Loysville, PA
3.	01568500	Clark Creek near Carsonville, PA
4.	01570000	Conodoguinet Creek near Hogestown, PA
5.	01575500	Codorus Creek near York, PA

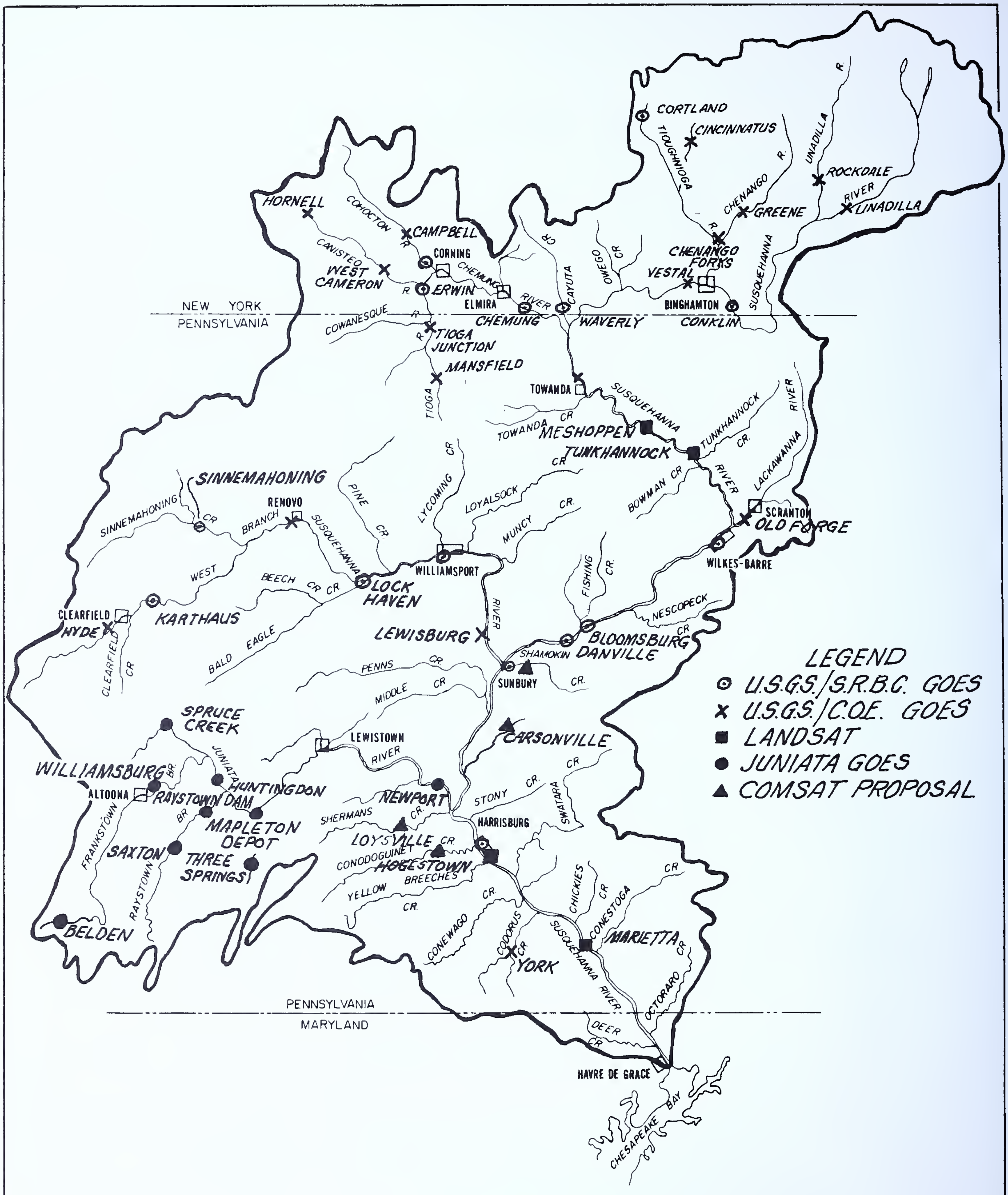

Figure 1. Location of Satellite Data Collection Platforms

APPENDIX D

CORPS OF ENGINEERS FLOOD CONTROL REGULATED RESERVOIRS

SUSQUEHANNA RIVER BASIN

Table 1) Upper Basin

Table 2) Lower Basin

KEY TO CHART

USGS Topo Quad Sheet: (NP) indicates that dam is not explicitly shown on map.

Flood Storage Capacity:

a) inches runoff refers to runoff average over entire upstream drainage.

b) acre feet is the amount of water covering one acre to a depth of one foot.

TABLE 1 - CORPS OF ENGINEERS FLOOD CONTROL REGULATED RESERVOIRS - UPPER BASIN - OCTOBER 1976

NAME-UPSTREAM DRAINAGE AREA	LOCATION OF DAM		U S G S 7 1/2' TOPO QUAD SHEETS	PURPOSE	FLOOD STORAGE CAPACITY (to spillway crest)	KEY RIVER GAGES FOR REGULATION	RELEASES COORDINATED WITH:
	LATITUDE	LONGITUDE					
Whitney Point Lake 255 mi^2	42°20'30" On the Otselic R., 3/4 mi. US of mouth on Tioughnioga R., 24 mi. US of Binghamton, NY	75°58'00"	Whitney Point, NY Willet, NY	Flood Control Recreation	Winter Pool at elevation 966 ft.: 5.99 inches runoff; 81,500 acre-feet Summer Pool at elevation 973 ft. (May 15 to Nov. 30): 5.44 inches runoff; 74,000 acre-feet spillway crest 10.1 feet	NWS--Tioughnioga R. at Whitney Point, NY 01512500--Chenango R. near Chenango Forks, NY 01513500--Susquehanna R. at Vestal, NY	East Sidney Lake
East Sidney Lake 102 mi^2	42°19'30" On Ouleout Cr., 4 mi. US of mouth on Susquehanna R., 6 mi. US of Unadilla, NY, 75 mi. US of Binghamton, NY	75°13'30"	Franklin, NY (NP)	Flood Control Recreation	Winter Pool at elevation 1140 ft.: 5.84 inches runoff; 31,800 acre-feet Summer Pool at elevation 1150 ft.: 5.53 inches runoff; 30,200 acre-feet spillway crest 1203 feet	01500500--Susquehanna R. at Unadilla, NY Susquehanna R. at Conklin, NY	Whitney Point Lake
Almond Lake 56 mi^2	42°21'00" On Canacadea Cr., 3.5 mi. US of mouth on Canisteo R. at Hornell, NY	77°42'30"	Hornell, NY	Flood Control Recreation	Winter Pool at elevation 1250 ft.: 4.77 inches runoff; 14,150 acre-feet Summer Pool at elevation 1255 ft. (May 15 to Sept. 15): 4.61 inches runoff; 13,700 acre-feet spillway crest 1300 feet	01524500--Canisteo R. at Hornell, NY Canisteo R. at West Cameron, NY	(Tioga-Hammond Lakes) (Cowanesque Lake) Whitney Point Lake East Sidney Lake
Arkport Lake 31 mi^2	40°24'00" Headwaters of Canisteo R., 1.0 mi. west of Arkport, NY, 8.0 mi. US of Hornell, NY	77°43'00"	Arkport, NY	Flood Control	4.80 inches runoff 7,950 acre-feet spillway crest 1304 feet	None--Dam is "automatic" in that it has no adjustable outlets.	-----
Stillwater Lake 36.8 mi^2	41°42'00" Lackawanna R. 4.0 mi. US of Forest City, PA, 30 mi. US of Scranton, PA	75°29'30"	Forest City, PA	Flood Control Water Supply	Water Supply Lake elevation 1572 ft.: 5.94 inches runoff; 11,650 acre-feet spillway crest 1621 feet	01534500--Lackawanna R. at Archbald, PA	-----
Aylesworth Creek Lake 6.2 mi^2	41°31'30" On Aylesworth Creek at Archbald Borough, 1.0 mi. US of mouth on Lackawanna R., 10.0 mi. US of Scranton, PA	75°32'00"	Carbondale, PA (NP)	Flood Control Recreation	Lake at elevation 1108 ft.: 5.14 inches runoff; 1,700 acre-feet spillway crest 1150 feet	None--Dam is "automatic" in that it has no adjustable outlets.	-----
Cowanesque Lake 298 mi^2	41°59'00" On the Cowanesque R., 2.2 mi. US of mouth on Tioga R. at Lawrenceville, PA, 12 mi. south of Corning, NY	77°09'00"	Tioga, PA-NY (NP)	Flood Contro. Recreation	Winter Pool at elevation 1025 ft.: 5.51 inches runoff; 87,500 acre-feet Summer Pool at elevation 1045 ft.: 5.16 inches runoff; 82,000 acre-feet spillway crest 1117 feet	01520500--Tioga R. at Lindley, NY 01529950--Chemung R. at Corning, NY	Tioga-Hammond Lake Almond Lake
Tioga-Hammond Lakes 402 mi^2	41°54'00" Each Dam 2.0 mi. US of junction of Crooked Cr. (Hammond) and Tioga R. (Tioga)	77°08'30"	Tioga, PA-NY (NP)	Flood Control Recreation	Winter Pools: 5.60 inches runoff; 12,000 acre-feet Summer Pools: (May 15 to Sept. 15); 4.98 inches runoff; 106,600 acre-feet spillway crest 1131 feet	01520500--Tioga R. at Lindley, NY 01529950--Chemung R. at Corning, NY	Cowanesque Lake Almond Lake

TABLE 2 - CORPS OF ENGINEERS FLOOD CONTROL REGULATED RESERVOIRS - LOWER BASIN - OCTOBER 1976

NAME-UPSTREAM DRAINAGE AREA	LOCATION OF DAM LATITUDE	LOCATION OF DAM LONGITUDE	U S G S 7 1/2' TOPO QUAD SHEETS	PURPOSE	FLOOD STORAGE CAPACITY (to spillway crest)	KEY RIVER GAGES FOR REGULATION	RELEASES COORDINATED WITH:
Alvin R. Bush Dam Kettle Creek Lake 226 mi.^{2}	41°21'30" On Kettle Creek, 8.4 mi. US of mouth on West Branch Susquehanna R., 15 mi. US of Renovo, PA	77°55'30"	Keating, PA	Flood Control Recreation	Recreation Pool at elevation 841 ft.: 607 inches runoff; 73,200 acre-feet spillway crest 937 feet	01545500--West Branch Susquehanna R. at Renovo, PA 01551500--West Branch Susquehanna R. at Williamsport, PA	Foster Joseph Sayers Lake (WQ) Curwensville Lake First Fork Sinnemahoning Cr. Lake
Curwensville Lake 365 mi^2 Curwensville Dam	40°57'30" On West Branch Susquehanna R., 2.6 mi. US of Curwensville, PA, 87 mi. US of Renovo, PA	78°31'30"	Curwensville, PA	Flood Control Recreation Water Quality	Winter Pool at elevation 1155 ft.: 6.36 inches runoff; 118,200 acre feet Summer Pool at elevation 1162 ft. (May 15 to Nov. 15): 5.88 inches runoff; 114,700 acre-feet spillway crest 1228 feet	--West Branch Susquehanna R. at Clearfield, PA --West Branch Susquehanna R. at Karthaus, PA 01545500--West Branch Susquehanna R. at Renovo, PA	Foster Joseph Sayers Lake (WQ) Kettle Creek Lake First Fork Sinnemahoning Cr. Lake
Foster Joseph Sayers Lake 339 mi^2 Foster Joseph Sayers Dam	41°02'30" On Bald Eagle Creek, 1.0 mi. US of Blanchard, PA, 14 mi. above the mouth.	77°36'30"	Beech Creek, PA (NP)	Flood Control Recreation Water Quality	Winter Pool at elevation 610 ft. (Nov. 15 to Mar. 15): 5.12 inches runoff; 92,700 acre-feet Summer Pool at elevation 630 ft. (Midway to Nov. 15): 3.87 inches runoff; 70,200 acre-feet	01545800--West Branch Susquehanna R. at Lock Haven, PA 01551500--West Branch Susquehanna R. at Williamsport, PA --Bald Eagle Creek at Beech Creek Station	Kettle Creek Lake (WQ) Curwensville Lake (WQ) First Fork Sinnemahoning Creek (WQ)
First Fork Sinnemahoning Creek Lake 243 mi^2 George B. Stevenson Dam	41°24'30" On First Fork Sinnemahoning Cr., 8.0 mi. above its mouth on Sinnemahoning Cr., 28 mi. US of Renovo, PA	78°01'00"	First Fork, PA	Flood Control Recreation Water Quality	Conservation Pool at elevation 920 ft.: 5.73 inches runoff; 73,800 acre-feet spillway crest 1026 feet	01545500--West Branch Susquehanna R. at Renovo, PA 01551500--West Branch Susquehanna R. at Williamsport, PA	Foster Joseph Sayers Lake (WQ) Curwensville Lake Kettle Creek Lake
Raystown Lake 960 mi^2 Raystown Dam	40°26'00" On the Raystown Branch of the Juniata R., 5.5 mi. US of mouth Juniata River	78°00'30"	Huntingdon, PA	Flood Control Recreation Low-Flow	Conservation Pool at elevation 786 ft.: 4.85 inches runoff; 514,000 acre-feet spillway crest 812 feet	01563500--Juniata River at Mapleton Depot, PA	-----
York Indian Rock Lake 93.7 mi^2 Indian Rock Dam	39°55'30" On Codorus Creek, 700 ft. above its junction with S. Br. Codorus Creek, 2.5 mi. above York, PA	76°45'00"	West York, PA	Flood Control Water Supply	5.6 inches runoff 28,000 acre-feet spillway crest 435 feet	01575500--Codorus Creek near York, PA	-----

APPENDIX E

RECOMMENDED ADDITIONS TO AUTOMATIC PRECIPITATION GAGE NETWORK

Susquehanna River Basin

Table 1 -- Upper Basin

Table 2 -- Lower Basin

TABLE 1

Recommended Additions to Automatic Precipitation Gage Network

Upper Basin
June 1977
(Page 1 of 1)

Gage Site	Location		New Site	Automate Present Site	Satellite Platform
Bath, NY	42°21'	77°21'		X	X
Tabor Corners, NY	42°40'	77°33'	X		
Canisteo, NY	42°17'	77°36'	X		X
Addison, NY	42°06'	77°14'		X	
Westfield, PA	41°51'	77°32'	X		
Jackson Summit, PA					X
Dunning, PA	41°55'	76°47'	X		
Hornby, PA	42°14'	77°03'			X
Richfield Spr., NY	42°52'	75°00'	X		
Unadilla, NY	42°19'	75°19'		X	
S. Hartwick, NY	42°35'	75°03'	X		
Davenport, NY	42°28'	74°51'			X
Rockwells Mills, NY	42°30'	75°25'	X		
N. Edmonston, NY	42°44'	75°16'			X
Sangerfield, NY	42°56'	75°21'	X		
Greene, NY	42°20'	75°46'		X	X
Plymouth, NY	42°40'	75°41'	X		X
Fabius, NY	42°56'	76°00'	X		
Chenango, NY	42°38'	75°58'	X		X
Nineveh, NY	42°12'	75°36'	X		X
Stevens Point, PA	41°58'	75°31'	X		
Montrose, PA	41°50'	75°52'			X
Orwell, PA	41°56'	76°16'	X		
Vestal, NY	42°06'	76°03'	X		
Willseyville, NY	42°22'	76°24'	X		
Halsey Valley, NY	42°08'	76°23'	X		
Newark Valley	42°13'	76°12'			X

TABLE 2

Recommended Additions to Automatic Precipitation Gage Network

Lower Basin
June 1977
(Page 1 of 2)

Gage Site	Location	New Site	Automate Present Site	Satellite Platform
Burlington, PA	41°47' 76°37'			X
Mehoopany, PA	41°35' 76°03'	X		X
Wheelerville, PA	41°36' 76°46'	X		
Rushville, PA	41°47' 76°07'		X	
Hop Bottom, PA	41°44' 75°42'	X		
Wilkes-Barre, PA	41°17' 75°51'		X	X
Brandonville, PA	40°56' 76°15'	X		X
Drums, PA	41°03' 75°57'	X		
Danville, PA	40°58' 76°37'		X	
Shickshinny, PA	41°12' 76°08'		X	
Walton, PA	41°47' 77°46'	X		
Rexford, PA	41°45' 77°31'	X		X
Penfield, PA	41°13' 78°30'	X		
St. Marys, PA	41°27' 78°26'	X		
Sizerville, PA	41°36' 78°10'			X
Berwindale, PA	40°48' 78°34'	X		
Burnside, PA	40°51' 78°47'	X		
Philipsburg, PA	40°57' 78°14'	X		X
Carrolltown, PA	40°35' 78°42'		X	X
Camp Kline, PA	41°17' 77°18'	X		
State College, PA	40°48' 77°52'		X	
Orviston, PA	41°07' 77°46'	X		
Lamar, PA	41°00' 77°32'	X		X
Glen Union, PA	41°14' 77°34'	X		
Bodines, PA	41°28' 77°00'		X	X
Mile Run, PA	41°07' 77°06'	X		X
Unityville, PA	41°18' 76°33'			X

TABLE 2

Recommended Additions to Automatic Precipitation Gage Network

Lower Basin
June 1977
(Page 2 of 2)

Gage Site	Location		New Site	Automate Present Site	Satellite Platform
Wharton, PA	41°33'	77°58'	X		X
Renovo, PA	41°14'	77°46'			X
Schellsburg, PA	40°04'	78°40'	X		
Everett, PA	40°01'	78°23'	X		X
Altoona, PA	40°31'	78°23'	X		
Blue Knob, PA	40°20'	78°34'			X
Huntingdon, PA	40°30'	78°01'		X	X
Greenwood Furn., PA	40°40'	77°48'	X		
Wells Tannery, PA	40°05'	78°07'	X		
Shade Gap, PA	40°11'	77°52'			X
Bannerville, PA	40°45'	77°21'	X		X
Ickesburg, PA	40°32'	77°22'	X		
New Berlin, PA	40°53'	77°04'	X		
Greenbriar, PA	40°45'	76°40'	X		X
Roxbury, PA	40°07'	77°40'	X		
Bloserville, PA	40°16'	77°22'			X
Glen Rock, PA	39°48'	76°44'	X		
East Berlin, PA	39°57'	76°59'	X		
Kirkwood, PA	39°51'	76°06'	X		

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